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SUPERSONIC TRANSPORT PROGRAM
PHASE II-C

BIMONTHLY TECHNICAL PROGRESS REPORT

CONTRACT FA-SS-66-5

D6-18110-6

July 1966

Best Available Copy

THE BOEING COMPANY
SUPERSONIC TRANSPORT DIVISION

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SUPERSONIC TRANSPORT PROGRAM
PHASE II-C

BIMONTHLY TECHNICAL PROGRESS REPORT

CONTRACT FA-SS-66-5

D6-18110-6

July 1966

PREPARED FOR

FEDERAL AVIATION AGENCY

Supersonic Transport Development Program

PREPARED BY Robert E. Oestreich

APPROVED BY Hans Behie

THE BOEING COMPANY
SUPERSONIC TRANSPORT DIVISION

ISSUE NO. ____

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D--18110-6

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ILLUSTRATIONS (Continued)

ILLUSTRATIONS (Continued)

ILLUSTRATIONS (Concluded)

TABLES

TABLES (Concluded)

I SUMMARY OF PROGRESS

A. CONFIGURATION DEVELOPMENT

The B-2707 configuration has been undergoing refinement as a result of comprehensive coordination with the airlines, wind tunnel testing, and further analysis. As a result of requests from a majority of the airlines, the gross weight of the airplane has been changed to 675,000 pounds to provide the desired improvements in range-payload characteristics. In response to airline requests and recognition of proposed new FAR revisions for improved passenger evacuation safety, the body has been lengthened to 306 feet to provide for rearrangement and resizing of doors, galleys, and other services. The wing loading has been changed to 75 pounds per square foot to provide a more optimum trade between the requirements of best cruise performance, wing weight, and fuel volume.

B. MATERIALS DEVELOPMENT

The high temperature test program for integral fuel tank insulation was successfully completed. A 31-inch by 10-inch panel coated with a fluorinated elastomer was subjected to 100,000 cycles of tension-compression loading at 450° F. without failure of the insulation material. An identical panel is now being subjected to cold temperature testing.

A comprehensive test program has been underway for several months to develop a titanium surface treatment as a preparation for adhesive bonding. It has been determined that Pasa Jell 107 is the optimum prebond surface process and preparation of a process specification has begun.

C. MOCKUP

Construction of the Class I full-scale mockup is continuing on schedule. As of late July completion status was as follows: fuselage - 90%, wing - 60%, empennage - 86%, and passenger compartment interior - 55%.

D. WING PIVOT BEARING DEVELOPMENT

After 300,000 cycles on quarter-scale wing pivot bearings -11 and -12, test pressure was increased from 8,850 to 12,500 pounds per square inch. At 400,000 cycles, the bearings were removed and inspected. Wear measurements showed only 10% wear on the bearing liners. The testing will be resumed.

The full-scale wing pivot bearing successfully completed 30,101 cycles prior to shutdown due to a crack in the test fixture support lug. A new Ti6AL-4V lug is being fabricated and test resumption is expected late in the year.

D. WING PIVOT BEARING DEVELOPMENT (Continued)

A technique for measuring bearing liners wear by an electrical resistance method has been developed and is being used in the 2-inch wing pivot bearing test program. Results to date have been good and the technique is considered to have good potential for use on the B-2707 for continuous monitoring or spot-checking by maintenance personnel.

E. ALL-ENGINE-OUT AIRPLANE CONTROLABILITY

The Pratt and Whitney engine has been found to be capable of supplying sufficient windmilling power for airplane controlability in an all-engine-out condition, including takeoff and landing. The General Electric engine does not have this capability, thus a ram air turbine will be required to provide the control power.

F. ENGINE INLET DEVELOPMENT

The variable diameter centerbody for the one-fifth scale model has been assembled and leak tested under simulated cruise pressure loads. Results of the leakage test show that the leakage between seals on the centerbody, under simulated cruise Mach number loads, was only 0.34 percent of the normal engine weight flow at cruise. The leakage rate with the highest pressure load found in any part of the inlet applied over the entire centerbody was only 0.73 percent of the normal engine weight flow. Both leakage rates are for the center-body fully expanded.

II. PROBLEM REPORT

HONEYCOMB PANEL CHARACTERISTICS NOT YET SUBSTANTIATED FOR LONG LIFE AT HIGH-TEMPERATURE AND HIGH-SONIC FATIGUE ENVIRONMENT (1101-1)

The structural integrity of honeycomb core sandwich is being investigated by use of thermal exposure followed by testing of the materials and components. Properties measured on materials tested after thousands of hours of exposure are considered conservative due to interim improvements in materials and processing methods. However, the data are of value in providing a basis for extrapolation of test data to the improved specimens. Data that follows include results from old and newly prepared specimens to show comparisons. Figures 1 and 2 show test results for resins used in the glass-reinforced laminates and adhesives that are subjected to thermogravimetric analysis (TGA) and differential thermal analysis (DTA) to evaluate cure characteristics and stability. The TGA of polyimide resins in air and inert atmosphere shows that the apparent burn-off point in air is approximately 1,050°F. This indicates continuous thermal stability in the 400 to 550°F service environment of the supersonic transport. Inert atmosphere increases the thermal stability due to absence of oxygen needed for degradation. The DTA shown in Fig. 2 indicates a curing reaction at about 300°F. The cure causes an endothermic reaction due to release of volatiles and water of reaction.

The tests performed in heated air on polyimide materials and structural components (resin, core, laminates, and adhesives), are much more drastic than SST service life conditions. Approximately one-twentieth the amount of oxygen is available at flight altitude than is present in heated air ovens used for exposure of test articles. It is expected that the stability of polyimide structure in actual service will approximate that observed in inert atmosphere testing.

Data from exposure tests was previously reported in the March 1966 Bimonthly Technical Progress report for test specimens having heat exposures up to 6,000 hours. At the present time, data for test exposures in a range of 8,500 to 16,000 hours are available and are shown in Fig. 3 and in Sec. III, Par. 1008.

Adhesives based on polyimide resins have been exposed and tested in lap bond shear specimens for as long as 16,000 hours at 500°F. The retention of bond strength is shown in Fig. 3. These values are measured on specimens prepared with a surface treatment of the substrate of lower quality than the one now in use.

The most advancement in sandwich components, since the first specimens were prepared for environmental conditioning, has been in honeycomb core. This improvement in properties is clearly presented in Table XXI, Sec. III, Par. 1008, of this report where the data from tests of new bias weave material (HRH 327) are plotted against older standard weave material (HRH 324). These new data show the properties of the new core after exposure to 1,000 hours at 450°F. The exposure

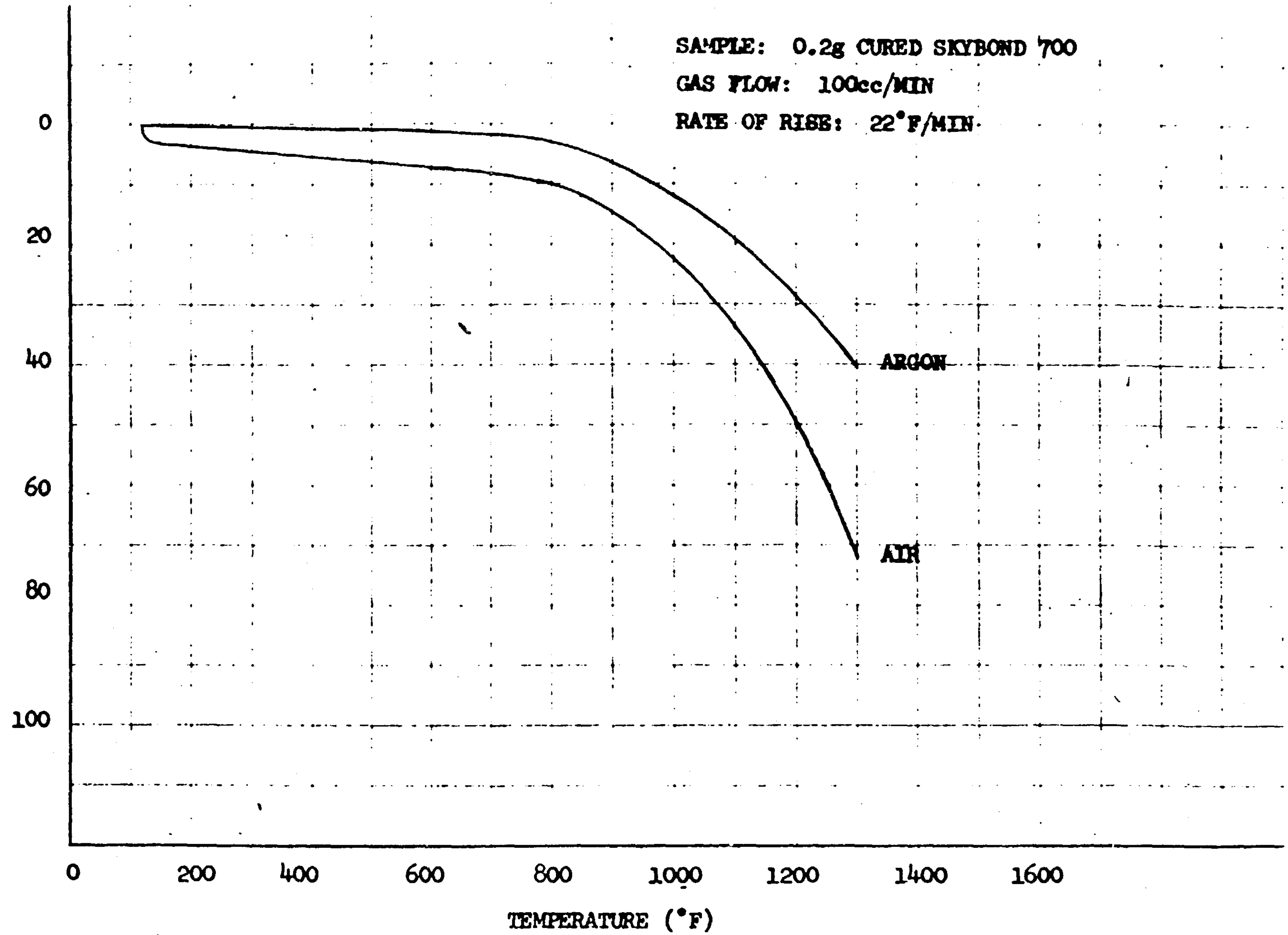


Figure 1. Thermogravimetric Analysis of Skybond 700

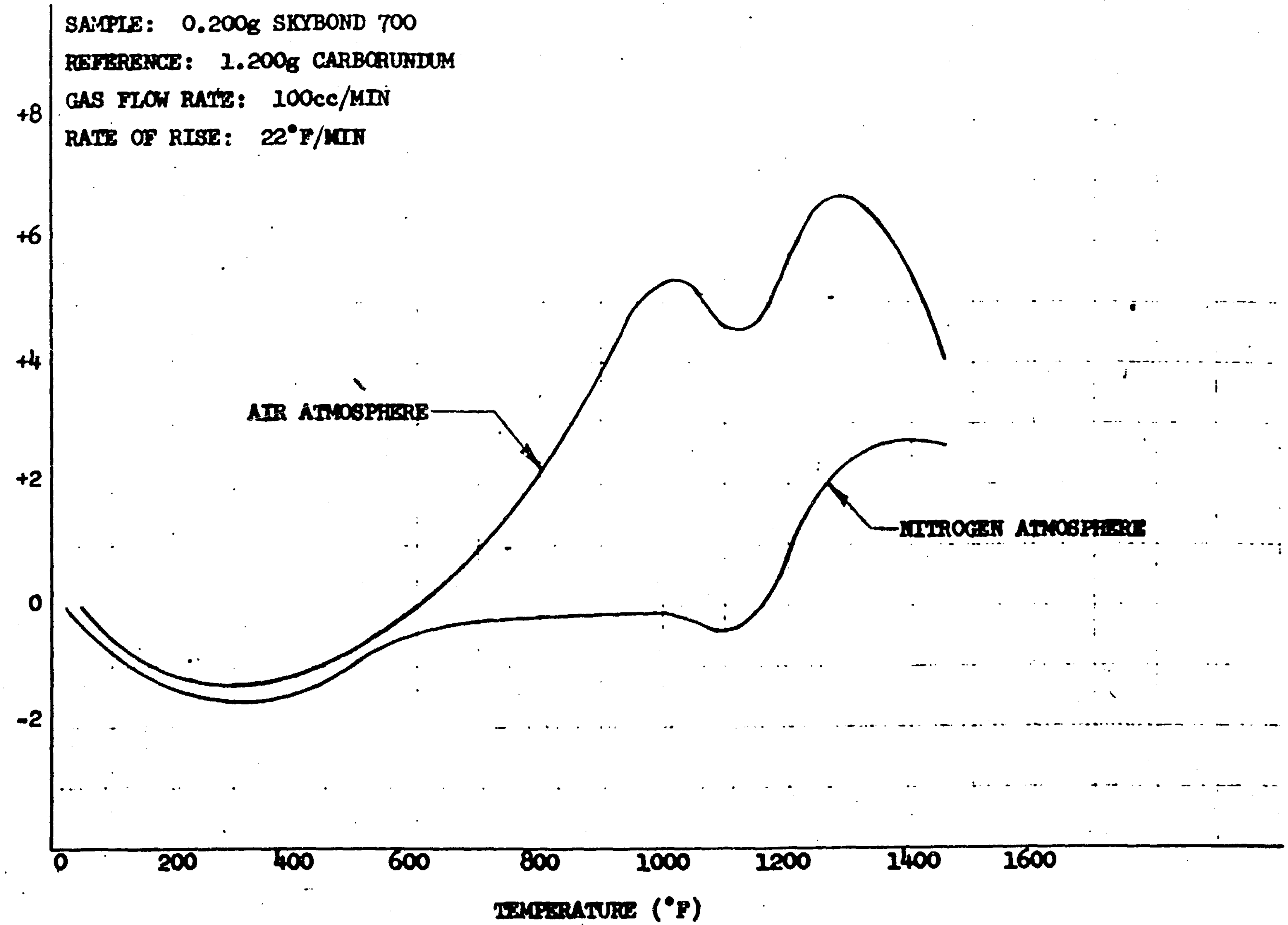


Figure 2. Differential Thermal Analysis of Skybond 700

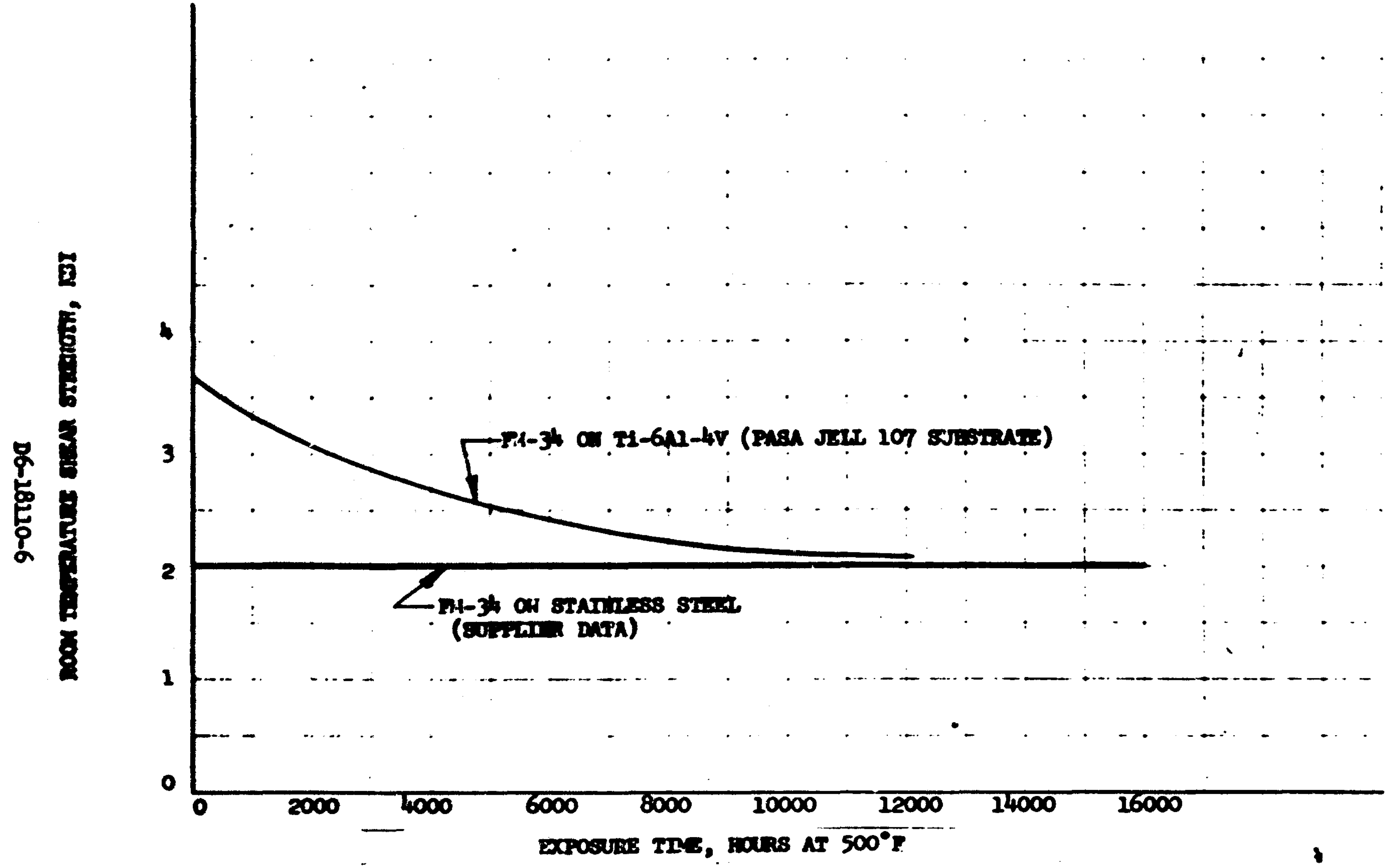


Figure 3. Effect of Thermal Exposure on Polyimide Adhesive (FM-34)

II. Problem Report (continued)

of both types of core is continuing. Based on the trends and the behavior of the adhesives and laminates, the loss of strength will be small as exposure time is extended.

The honeycomb panel development tests of both materials and components have been encouraging up to this point on the program, even though the high temperature life characteristics are not yet as good as desired. The test program is continuing for further validation of test results. No problems are anticipated in the development of panels that will be satisfactory for the SST environment.

III. DESCRIPTION OF TECHNICAL PROGRESS

10. AIRFRAME GENERAL

1001. System Integration

10010. SYSTEM INTEGRATION, GENERAL

Formal release of the system requirements analysis data is planned in early August. This release will include identification of all subsystem functional characteristics, identified in matrix form against each element of the flight mission, as well as in flow diagram form. Subsystem interfaces with elements of ground operations will also be identified within the matrix.

An initial draft of the Environmental Integration section of the Operational Suitability document has been completed and is currently being reviewed.

A preliminary issue of the SST Engineering Trade Studies, D6A10187-1, was released for review and comment. One hundred and four significant studies have been identified and 23 studies have been summarized to date.

A weights control program, which includes regular reviews, was conducted during the reporting period. Major areas of weight reduction were identified and design changes were authorized to incorporate these savings.

Release of newly developed subsystem specifications to the FAA was accomplished on June 28 in accordance with the Phase II-C contract. Review and updating of these specifications is currently in progress. A meeting has been scheduled with the FAA in Washington, D.C., August 2 and 3 to receive FAA comments on the June release.

10011. CONFIGURATION DEVELOPMENT

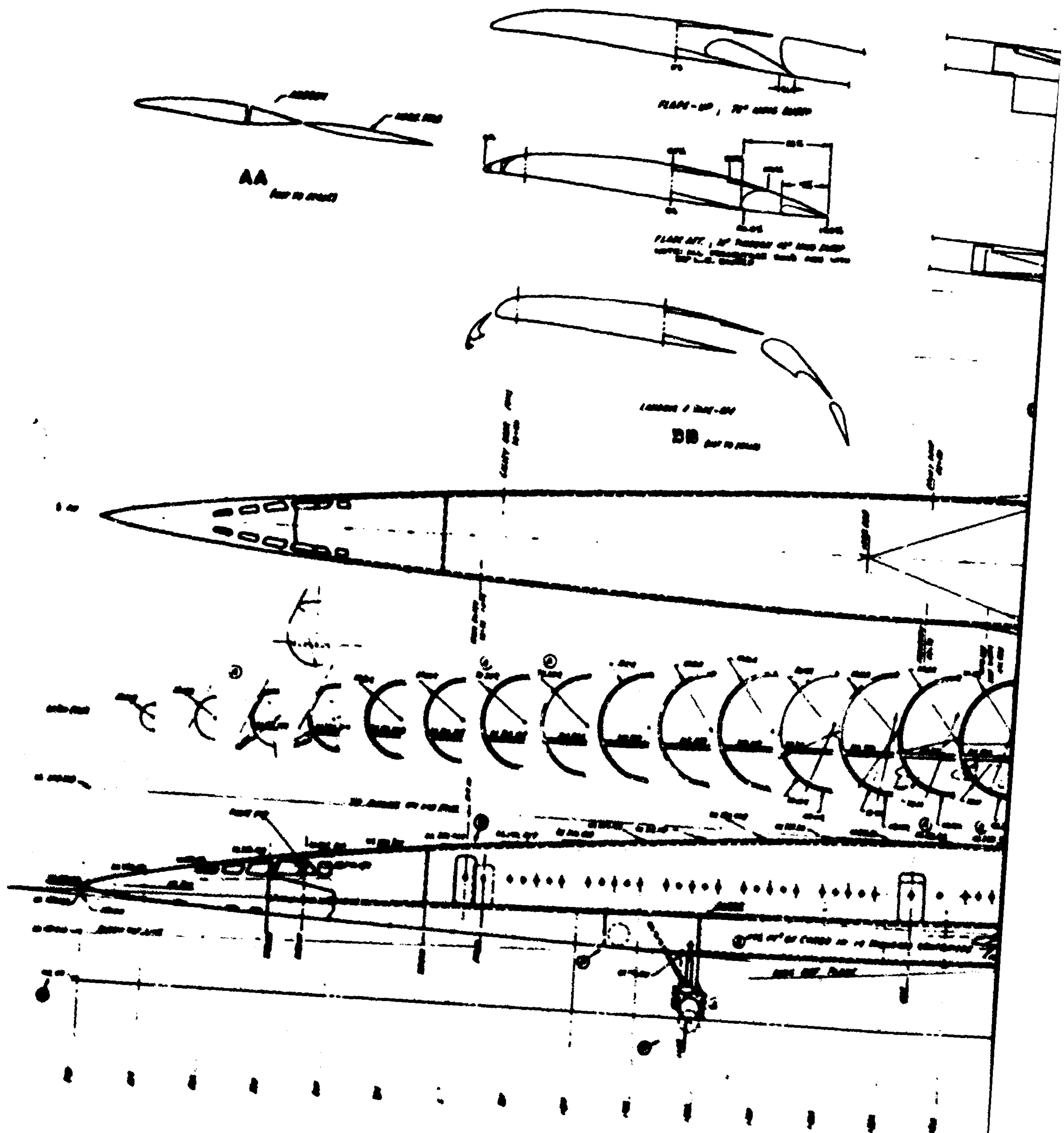
The May 1966 Bimonthly Technical Progress Report gave details of a B-2707 configuration having a gross weight of 600,000 pounds. This configuration has since been undergoing refinements as a result of extensive coordination with the airlines, wind tunnel testing, and analysis. Some of the more important changes being incorporated are described as follows: (See Fig. 4.)

- Gross Weight - In order to be responsive to the majority of the potential airline customer range-payload requirements, the takeoff gross weight is being changed from 600,000 to 675,000 pounds.

- Wing Loading - The wing loading of the present airplane has been changed from 65 to 75 pounds per square foot to provide a more optimum trade between the requirements of best cruise performance, wing weight, and fuel volume.

- Interior Arrangement - The body has been lengthened from 298 to 306 feet to provide for rearrangement and resizing of doors, galleys, and other services in response to the airline coordination committee's recommendations. The proposed FAR revisions for improved safety of passengers during evacuation were also influencing factors.

A preliminary inboard profile drawing of the latest configuration is given in Fig. 5.



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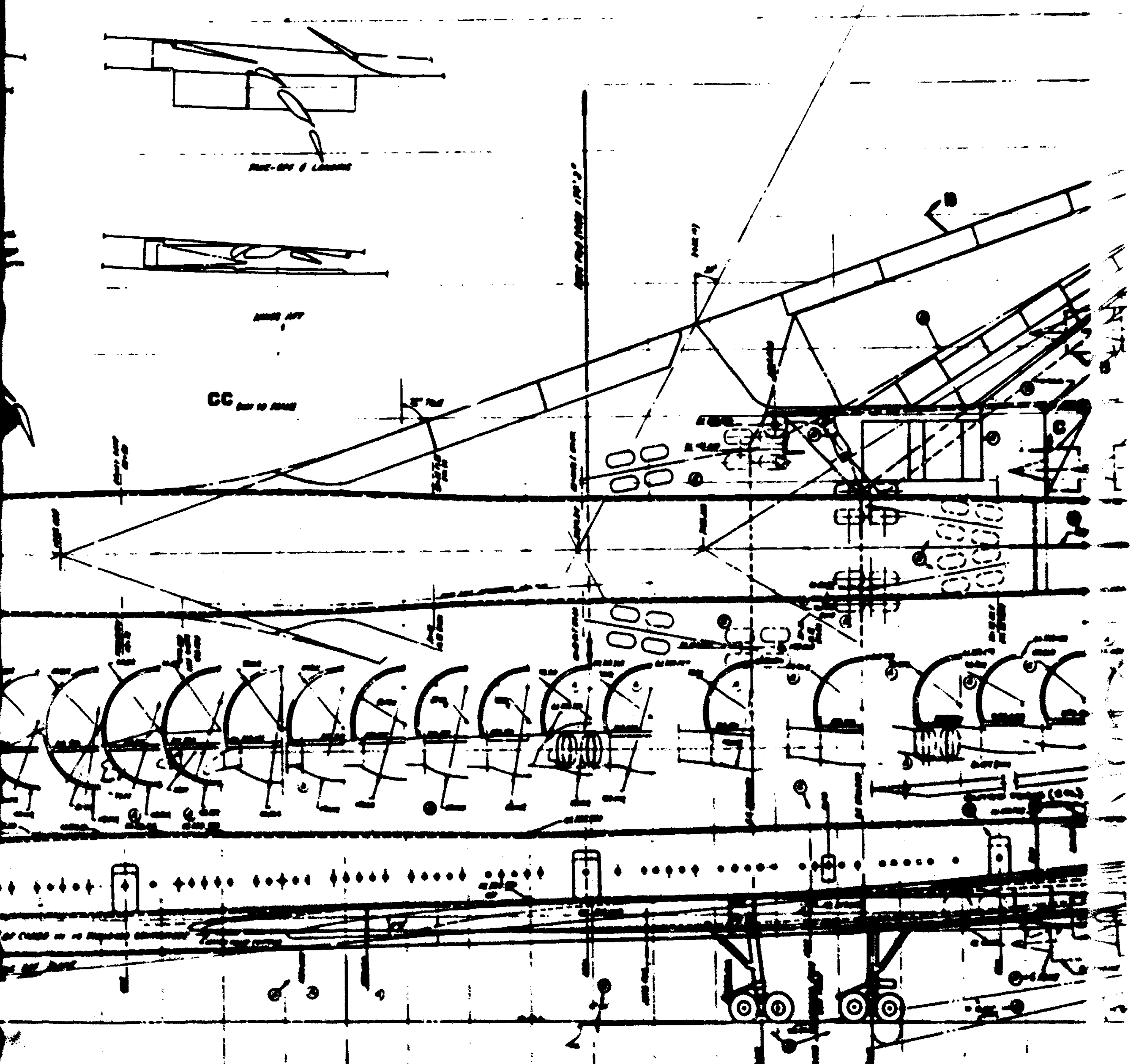

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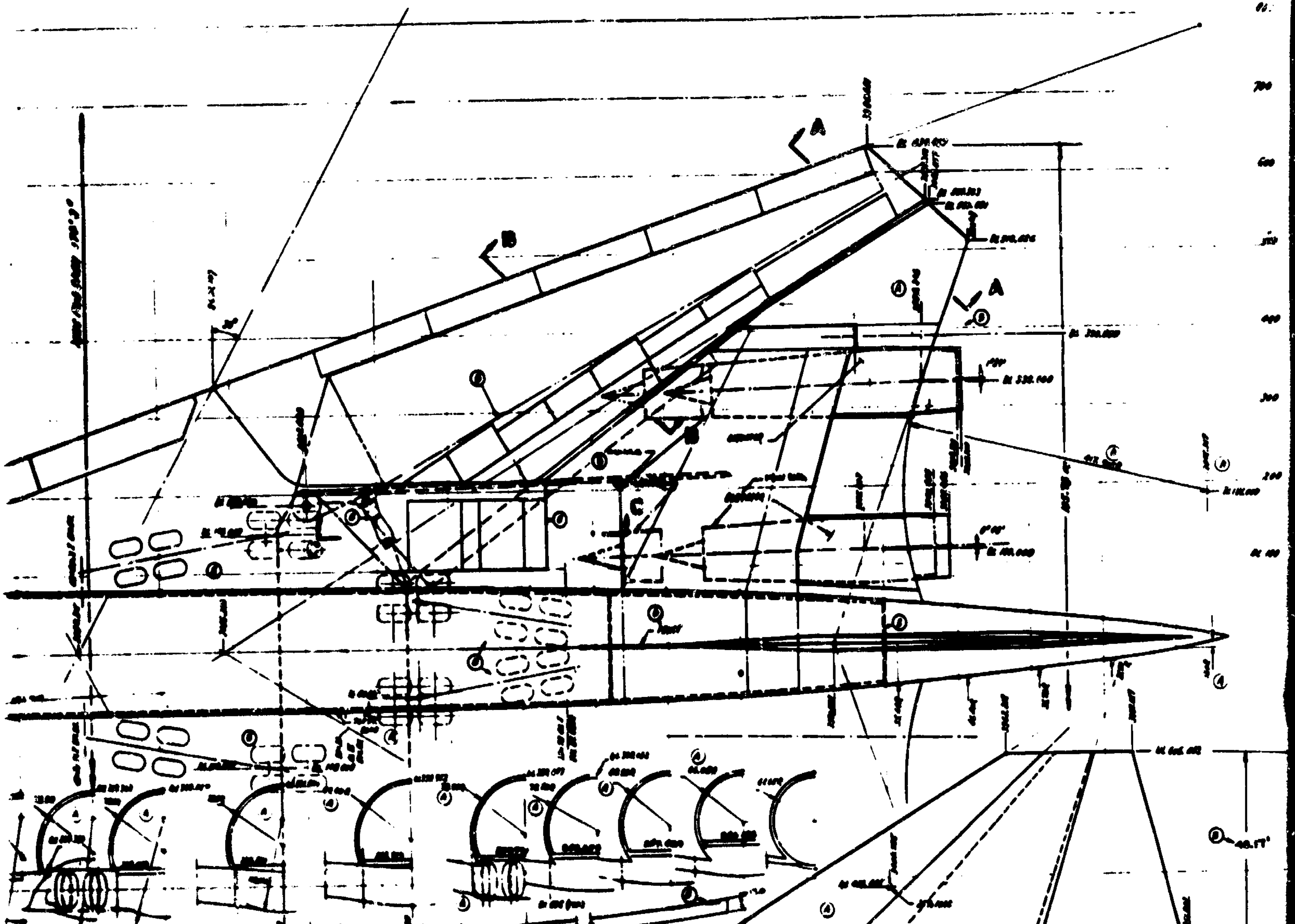

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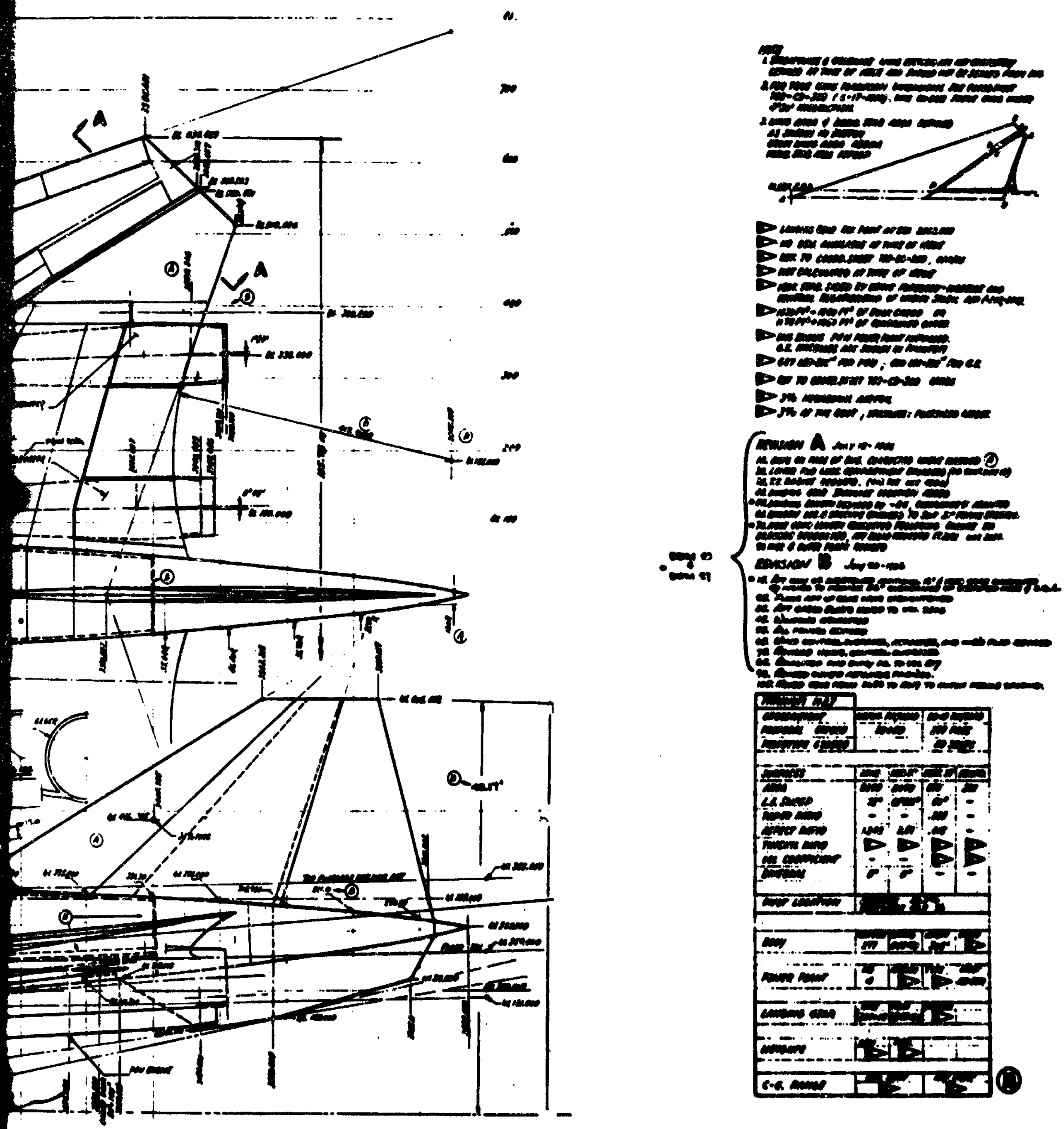
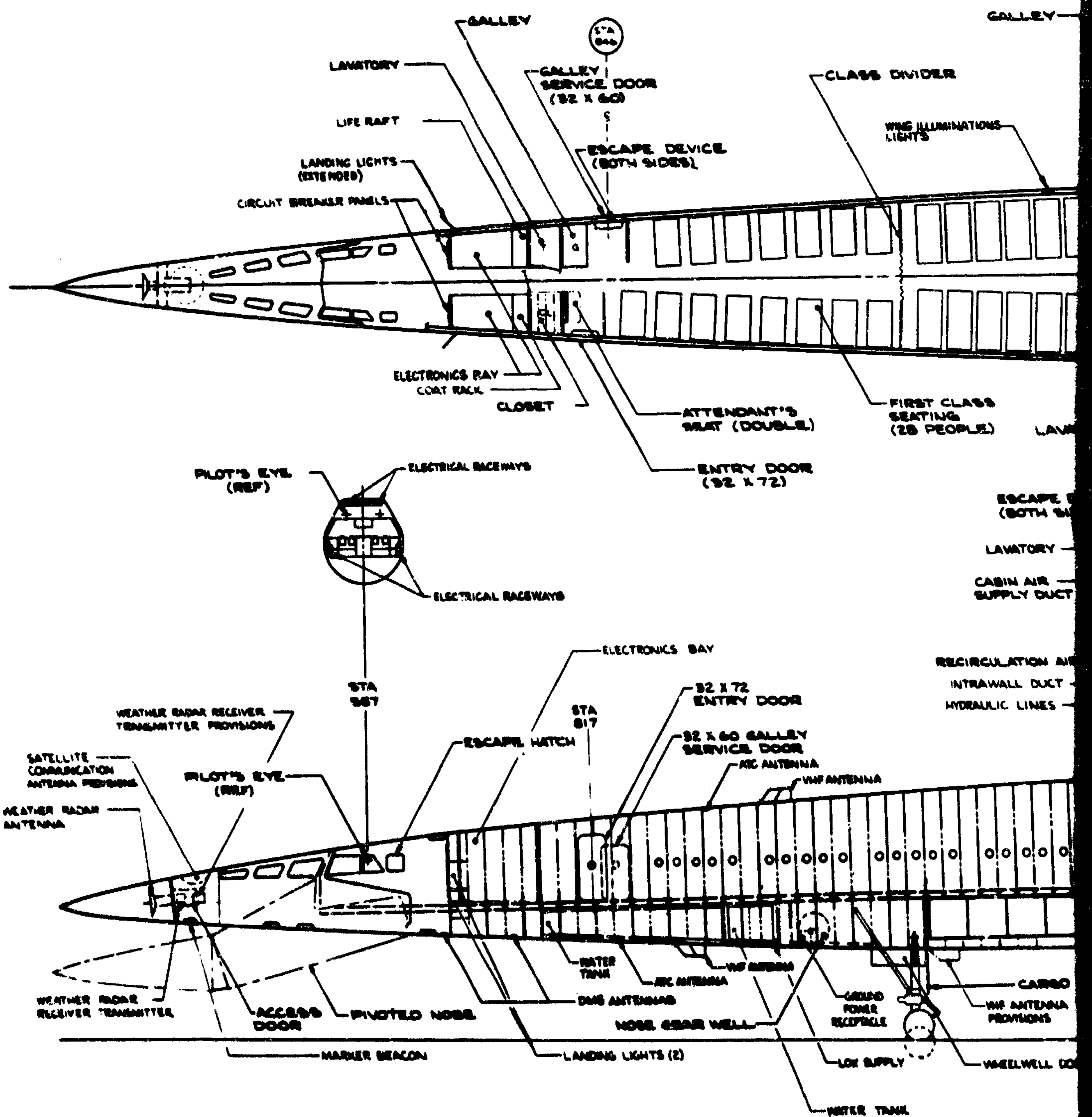
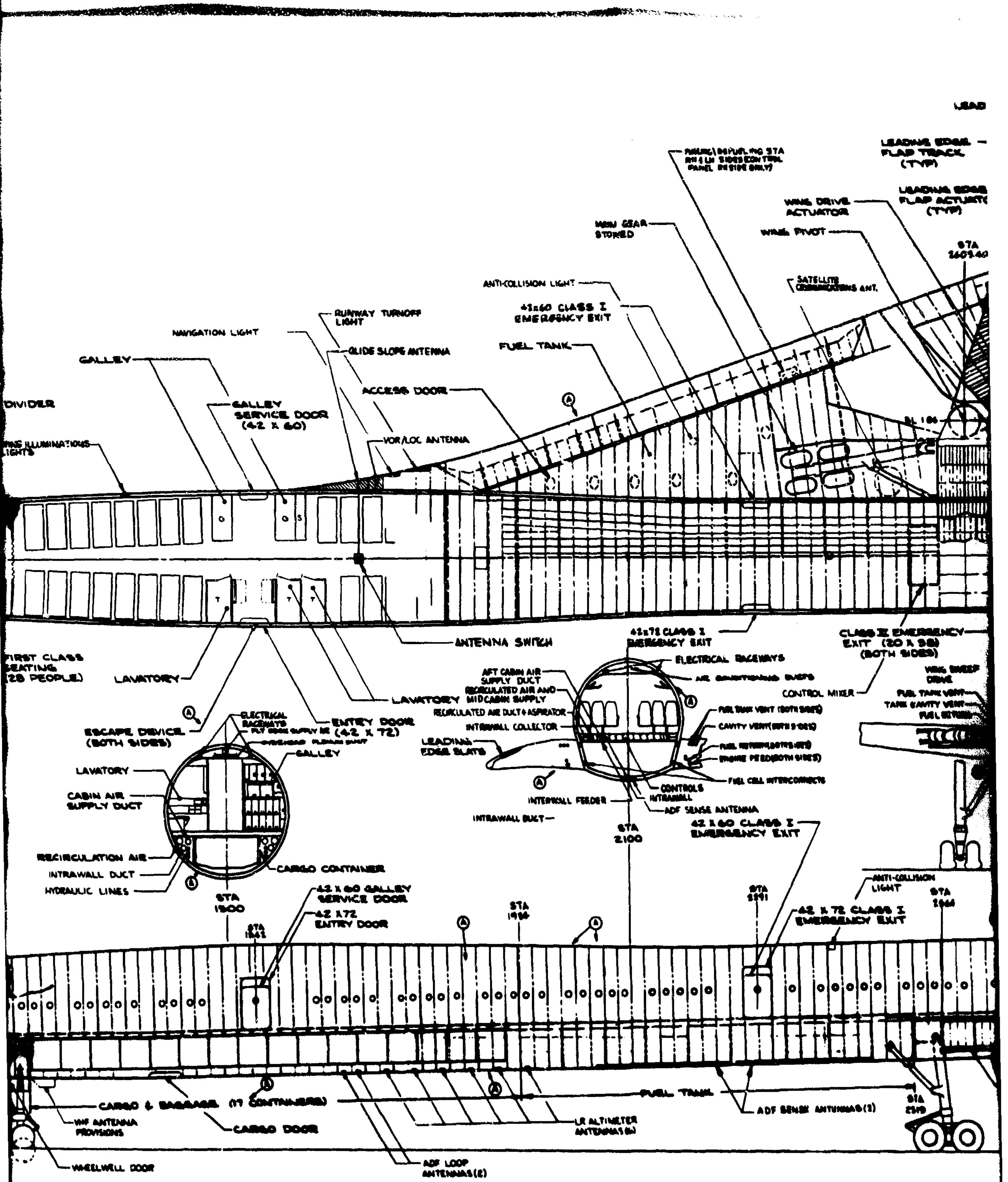


Figure 4. General Arrangement Model B-2707

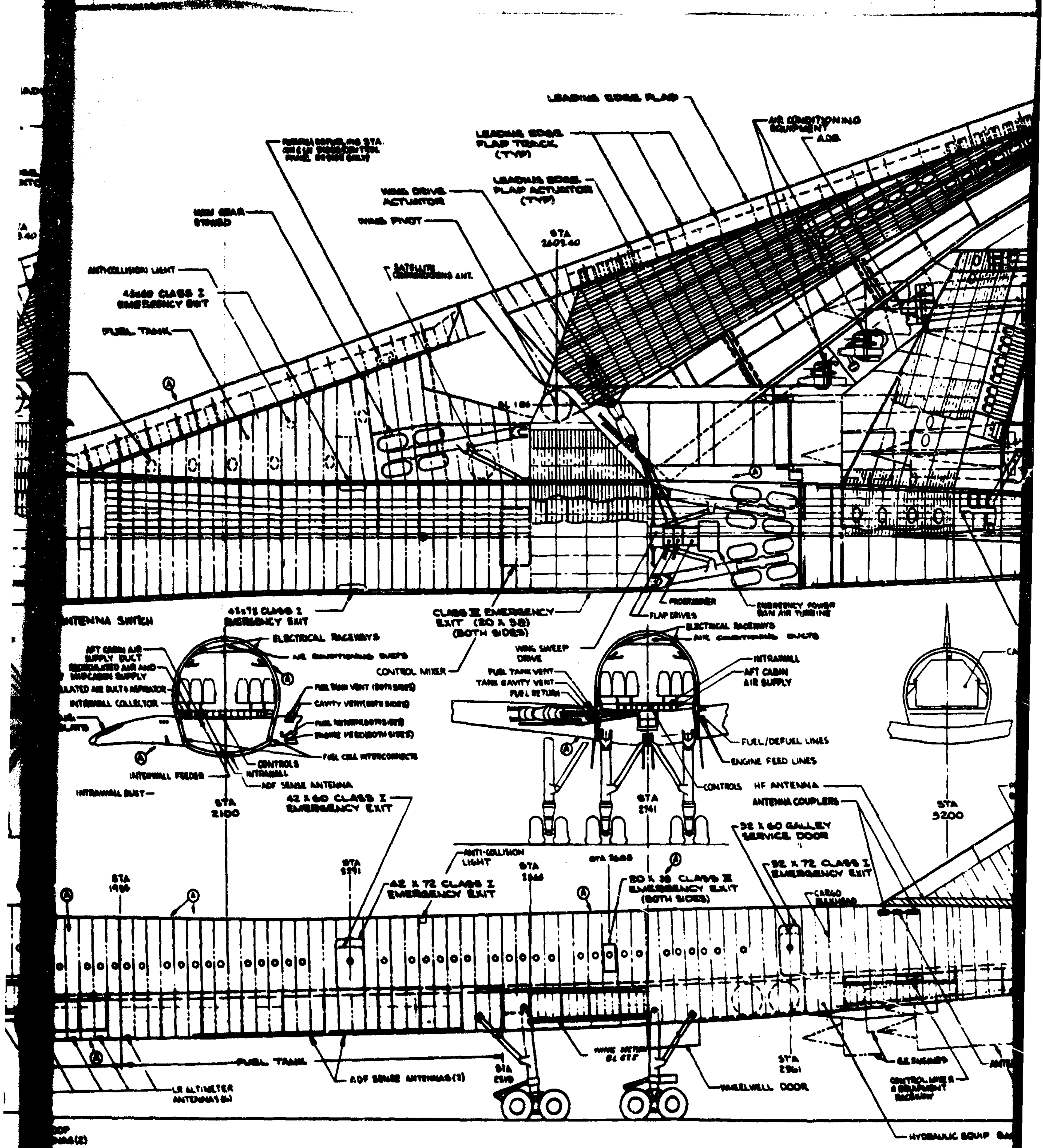

GALLEY
STA 846
LAVATORY
GALLEY SERVICE DOOR (32 X 60)
CLASS DIVIDER
LIFE RAFT
WING ILLUMINATIONS LIGHTS
ESCAPE DEVICE (BOTH SIDES)
LANDING LIGHTS (EXTENDED)
CIRCUIT BREAKER PANELS
ELECTRONICS BAY
COAT RACK
CLOSET
ATTENDANT'S SEAT (DOUBLE)
FIRST CLASS SEATING (28 PEOPLE)
ENTRY DOOR (32 X 72)
PILOT'S EYE (REF)
ELECTRICAL RACEWAYS
ELECTRICAL RACEWAYS
LAVATORY
CABIN AIR SUPPLY DUCT
INTRAWALL DUCT
HYDRAULIC LINES
ELECTRONICS BAY
STA 567
32 X 72 ENTRY DOOR
STA 817
WEATHER RADAR RECEIVER TRANSMITTER PROVISIONS
ESCAPE HATCH
32 X 60 GALLEY SERVICE DOOR
SATELLITE COMMUNICATION ANTENNA PROVISIONS
PILOT'S EYE (REF)
ATC ANTENNA
VHF ANTENNA
WEATHER RADAR ANTENNA
WATER TANK
ATC ANTENNA
VHF ANTENNA
DME ANTENNAS
GROUND POWER RECEPTACLE
CARGO
VHF ANTENNA PROVISIONS
WEATHER RADAR RECEIVER TRANSMITTER
ACCESS DOOR
PIVOTED NOSE
NOSE GEAR WELL
MARKER BEACON
LANDING LIGHTS (2)
LOX SUPPLY
WATER TANK

A



LEADING EDGE FLAP TRACK (TYP)
LEADING EDGE FLAP ACTUATOR (TYP)
WING DRIVE ACTUATOR
WING PIVOT
MAIN GEAR STOWED
SATELLITE COMMUNICATIONS ANT.
ANTI-COLLISION LIGHT
42x60 CLASS I EMERGENCY EXIT
RUNWAY TURNOFF LIGHT
NAVIGATION LIGHT
GLIDE SLOPE ANTENNA
FUEL TANK
GALLEY
ACCESS DOOR
DIVIDER
GALLEY SERVICE DOOR (42 X 60)
VOR/LOC ANTENNA
WING ILLUMINATIONS LIGHTS
ANTENNA SWITCH
42x72 CLASS I EMERGENCY EXIT
CLASS II EMERGENCY EXIT (20 X 38) (BOTH SIDES)
FIRST CLASS SEATING (28 PEOPLE)
LAVATORY
ELECTRICAL RACEWAYS
AIR CONDITIONING DUCTS
AFT CABIN AIR SUPPLY DUCT
RECIRCULATED AIR AND
LAVATORY
MIDCABIN SUPPLY
CONTROL MIXER
WING SWEEP DRIVE
FUEL TANK VENT
TANK CAVITY VENT
RECIRCULATED AIR DUCT & ASPIRATOR
FUEL TANK VENT (BOTH SIDES)
ESCAPE DEVICE (BOTH SIDES)
ENTRY DOOR (42 X 72)
INTRAWALL COLLECTOR
CAVITY VENT (BOTH SIDES)
LEADING EDGE SLATS
FUEL RETURN (BOTH SIDES)
ENGINE FEED (BOTH SIDES)
FUEL CELL INTERCONNECTS
LAVATORY
GALLEY
CABIN AIR SUPPLY DUCT
CONTROLS
INTRAWALL
INTERWALL FEEDER
ADF SENSE ANTENNA
INTRAWALL DUCT
STA 2100
42 X 60 CLASS I EMERGENCY EXIT
RECIRCULATION AIR
CARGO CONTAINER
INTRAWALL DUCT
HYDRAULIC LINES
STA 1500
42 X 60 GALLEY SERVICE DOOR
42 X72 ENTRY DOOR
ANTI-COLLISION LIGHT
42 X 72 CLASS I EMERGENCY EXIT
CARGO & BAGGAGE (17 CONTAINERS)
FUEL TANK
ADF SENSE ANTENNAS (2)
VHF ANTENNA PROVISIONS
CARGO DOOR
LR ALTIMETER ANTENNAS
WHEELWELL DOOR
ADF LOOP ANTENNAS (2)

B


LEADING EDGE FLAP
AIR CONDITIONING EQUIPMENT
LEADING EDGE FLAP TRACK (TYP)
LEADING EDGE FLAP ACTUATOR (TYP)
WING DRIVE ACTUATOR
WING PIVOT
STA 2602.40
MAIN GEAR STOWED
SATELLITE COMMUNICATIONS ANT.
ANTI-COLLISION LIGHT
42x60 CLASS I EMERGENCY EXIT
FUEL TANK
ANTENNA SWITCH
42x72 CLASS I EMERGENCY EXIT
ELECTRICAL RACEWAYS
CLASS III EMERGENCY EXIT (20 X 38) (BOTH SIDES)
CONTROL MIXER
PROGRAMMER
FLAP DRIVES
EMERGENCY POWER RAM AIR TURBINE
ELECTRICAL RACEWAYS
WING SWEEP DRIVE
FUEL TANK VENT
TANK CAVITY VENT
FUEL RETURN
INTRAWALL
AFT CABIN AIR SUPPLY
FUEL/DEFUEL LINES
ENGINE FEED LINES
CONTROLS
HF ANTENNA
ANTENNA COUPLERS
AFT CABIN AIR SUPPLY DUCT
INTERWALL COLLECTOR
CONTROLS
INTRAWALL
INTERWALL FEEDER
ADF SENSE ANTENNA
INTRAWALL DUCT
STA 2100
42 X 60 CLASS I EMERGENCY EXIT
STA 2741
STA 3200
32 X 60 GALLEY SERVICE DOOR
32 X 72 CLASS I EMERGENCY EXIT
CARGO BULKHEAD
ANTI-COLLISION LIGHT
42 X 72 CLASS I EMERGENCY EXIT
20 X 38 CLASS III EMERGENCY EXIT (BOTH SIDES)
STA 1986
FUEL TANK
ADF SENSE ANTENNAS (2)
LR ALTIMETER ANTENNAS (6)
STA 2961
WHEELWELL DOOR
CONTROL MIXER & EQUIPMENT RACEWAY
HYDRAULIC EQUIP BA

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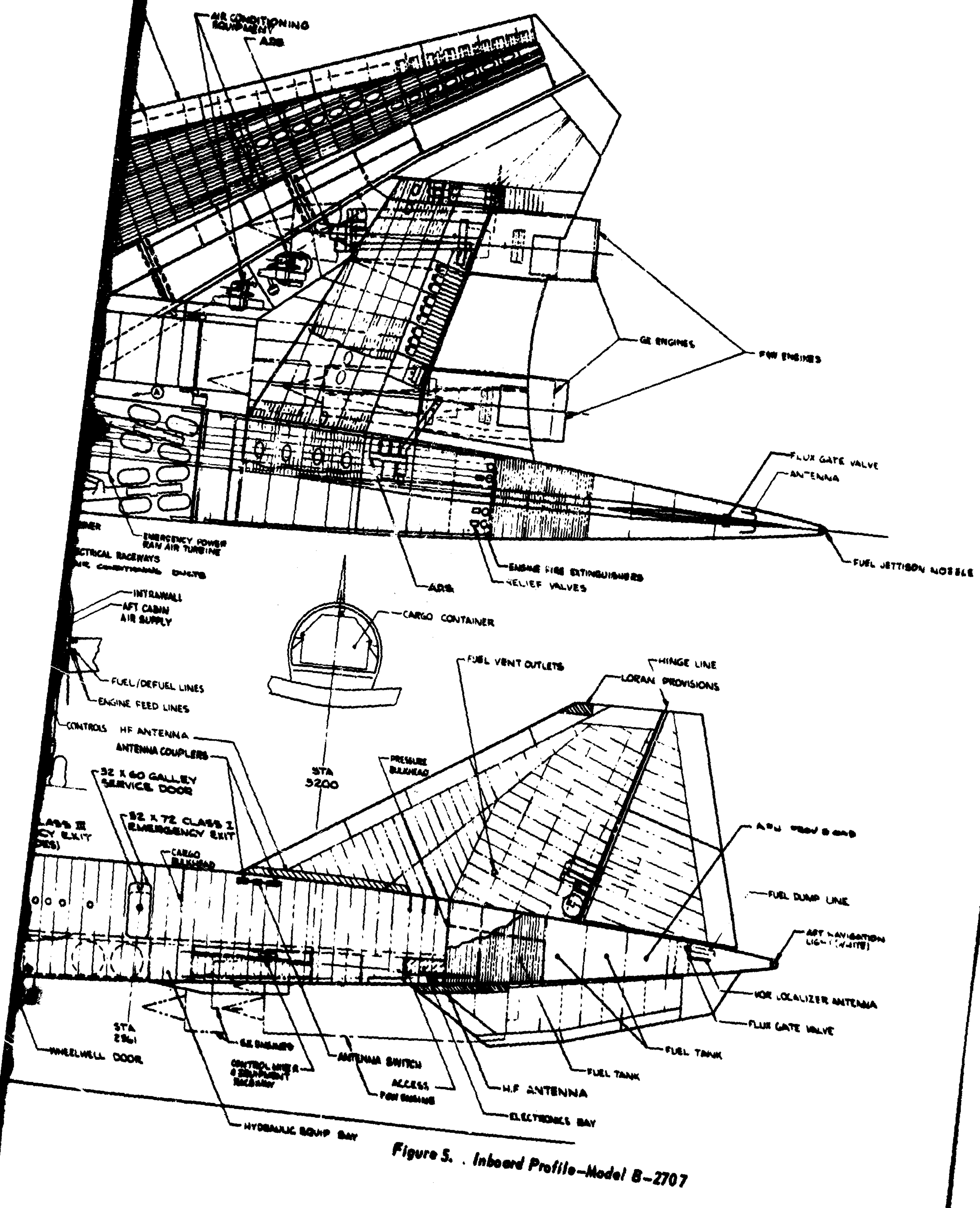


Figure 5. . Inboard Profile—Model B-2707

III. Description of Technical Progress (continued)

10013. WEIGHT AND BALANCE CONTROL ANALYSIS

The estimated weights for the B-2707 (GE), as revised for the higher gross weight, are shown in Table I. The weights reflect the intercontinental 277 mixed class interior for the production airplane. The design gross weights are given in Table II.

The increments for the P&W engines installed are as follows:

Nacelles	+1040 pounds
Engine instl	-3140
Airframe	- 400
OEW increment	-2500 pounds

Table I. Estimated Weights, B-2707

Reference B-2707 - GE	Production
WING GROUP	66,100
HORIZONTAL TAIL	20,300
VERTICAL TAIL	5,000
VENTRAL TAIL	550
BODY GROUP	47,300
MAIN LANDING GEAR	26,300
NOSE GEAR	1,520
NACELLE	9,200
TOTAL STRUCTURE	(176,270)
ENGINE (INCL TR & SS, WHERE APPL)	47,600
ENGINE ACCESSORIES	1,100
ENGINE CONTROLS	300
STARTING SYSTEM	400
BALLAST SYSTEM	150
FUEL SYSTEM	7,500
TOTAL PROPULSION GROUP	(57,050)
INSTRUMENTS	1,250
SURFACE CONTROLS	10,880
HYDRAULICS	3,600
ELECTRICAL	3,600
ELECTRONICS	2,320
FURNISHINGS	13,300
AIR CONDITIONING	5,500
ANTI-ICING	280
INSULATION	2,700
TOTAL FIXED EQUIPMENT	(43,430)
PROTOTYPE CONSTRUCTION (+6%)	
MANUFACTURER'S EMPTY WEIGHT	276,750
UNUSABLE FUEL	1,192
UNUSABLE OIL	252
EMERGENCY EQUIPMENT	472
UNUSABLE WATER - WASHING & DRINKING	10
TOILET WATER & CHEMICAL	150
GALLEY STRUCTURE	2,049
TOTAL STANDARD ITEMS	(4,125)
BASIC EMPTY WEIGHT	280,875
PLUG-IN FOOD TRAYS	55
CREW & CREW BAGGAGE	1,850
USABLE OIL	80
EMERGENCY EQUIPMENT	2,015
USABLE WATER - WASHING & DRINKING	384
PASSENGER SERVICE EQUIPMENT	720
FOOD & BEVERAGE	432
GALLEY SERVICE	639

Table I. (Concluded)

Reference B-2707 - GE	Production
LIQUOR SERVICE	393
LAVATORY SUPPLIES	57
TOTAL OPERATIONAL ITEMS	(6,625)
OPERATIONAL EMPTY WEIGHT	287,500
Max Design Taxi Weight	675,000

Note: All weights in pounds

Table II. Design Weights, B-2707

Model	Production	
Engine	P&WA	GE
Max design taxi weight	675,000	675,000
Max design takeoff weight flaps down	672,000	672,000
Max design flight weight flaps down	668,000	668,000
flaps up ($n = 2.5$)	666,000	666,000
Max design landing weight	420,000	430,000
Max zero fuel weight	360,000	362,500
Minimum flying weight	310,000	314,000
Operational empty weight	285,000	287,500
Allowable payload	75,000	75,000

Note: All weights in pounds

10013. Weight and Balance Control Analysis (continued)

The fuel use follows a simple sequence, with the first and last portions the same for any mission. The middle segments follow a logical pattern, depending only upon fuel distribution.

(1) Feed engines 1 and 4 from outboard auxiliary tanks 1A and 4A; feed engines 2 and 3 from forward auxiliary until auxiliary tanks 1A and 4A are empty.

The correct sequence is then obtained by selecting the appropriate steps from the following.

(2) With aft auxiliary fuel:

(a) When forward auxiliary fuel remains, feed engines 1 and 4 from aft auxiliary, feed engines 2 and 3 from forward auxiliary until depletion of one auxiliary.

(b) When no forward auxiliary fuel remains, feed all engines from aft auxiliary until depletion.

(3) With no aft auxiliary fuel, but with forward auxiliary fuel remaining:

(a) When the sum of main tanks 2 and 3, plus the forward auxiliary, is greater than main tanks 1 and 4, feed all engines from forward auxiliary.

(b) When the sum of main tanks 2 and 3, plus the forward auxiliary, equals main tanks 1 and 4, feed engines 2 and 3 from forward auxiliary, and feed engines 1 and 4 from main tanks 1 and 4.

(4) With no auxiliary tank fuel remaining:

(a) When fuel in main tanks 1 and 4 is greater than fuel in tanks 2 and 3, feed all engines from main tanks 1 and 4 until main tanks are equal.

(5) In all cases, descent and reserve fuel is equally distributed in main tanks 1, 2, 3, and 4.

The main tanks provide continuous backup during all auxiliary tank fuel use. Note that after initiation of fuel use from any tank, the tank is used to depletion, with no cycling required.

III. Description of Technical Progress (continued)

10013. Weight and Balance Control Analysis (continued)

The balance and loading of the production airplane is shown in Fig. 6. The general balance characteristics are typical of airplanes with aft-mounted engines. The relationship between the operational empty weight center of gravity and the aft limits was chosen to optimize the total airplane performance for payloads of 30,000 pounds and over. For lower payloads, restricted seating or ballast is required. A ballast water tank is installed forward of the nose gear, which provides rapid flexible control of the center of gravity location.

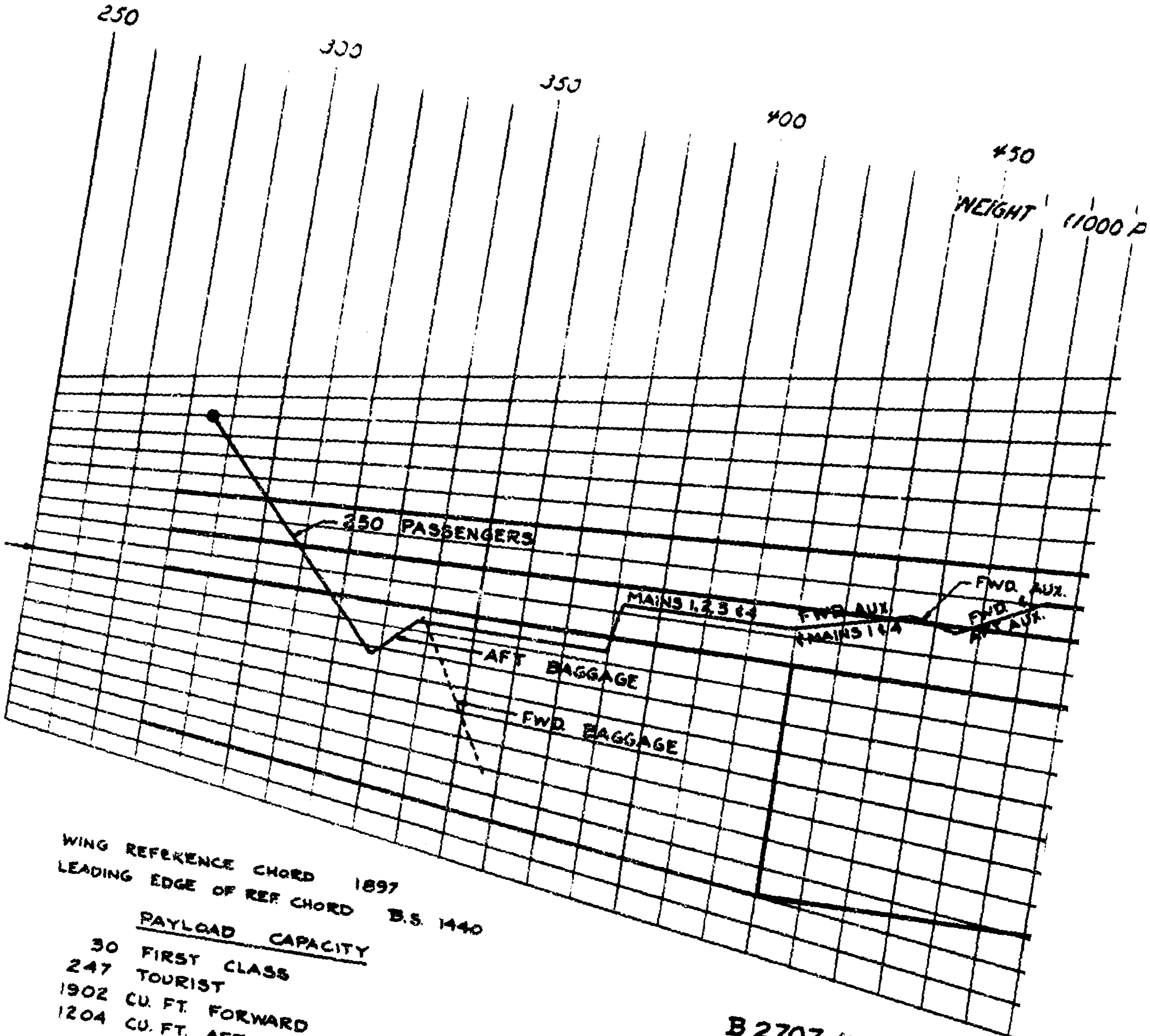
The fuel tank arrangement is shown in Fig. 7. A single fuel loading sequence will maintain the airplane center of gravity within acceptable limits, with no knowledge required of the payload other than the fact that the zero fuel condition must fall within the landing limits. When the payload distribution is known, rapid transfer of fuel between the forward and aft auxiliary fuel tanks may be performed at the operator's option if optimization of the airplane center of gravity for cruise performance is desired.

Fuel Loading

(1) Load main tanks 1, 2, 3, and 4 equally up to a total of 60,000 pounds.

(2) Load the following tanks by ratio. Outboard auxiliary tanks 1A and 4A: 50,450 pounds per tank (full); Forward auxiliary: 126,500 pounds; Main tanks 1 and 4: 12,800 pounds per tank (full).

(3) Load the following tanks by ratio. Forward auxiliary: 10,500 pounds (full); Aft auxiliary: 18,000 pounds; Main tanks 2 and 3: 12,800 pounds per tank (full).



WING REFERENCE CHORD 1897
LEADING EDGE OF REF CHORD B.S. 1440

PAYLOAD CAPACITY

30 FIRST CLASS
247 TOURIST
1902 CU. FT. FORWARD
1204 CU. FT. AFT

B 2707 (P&W)
50,000 POUND PAYLOAD

A

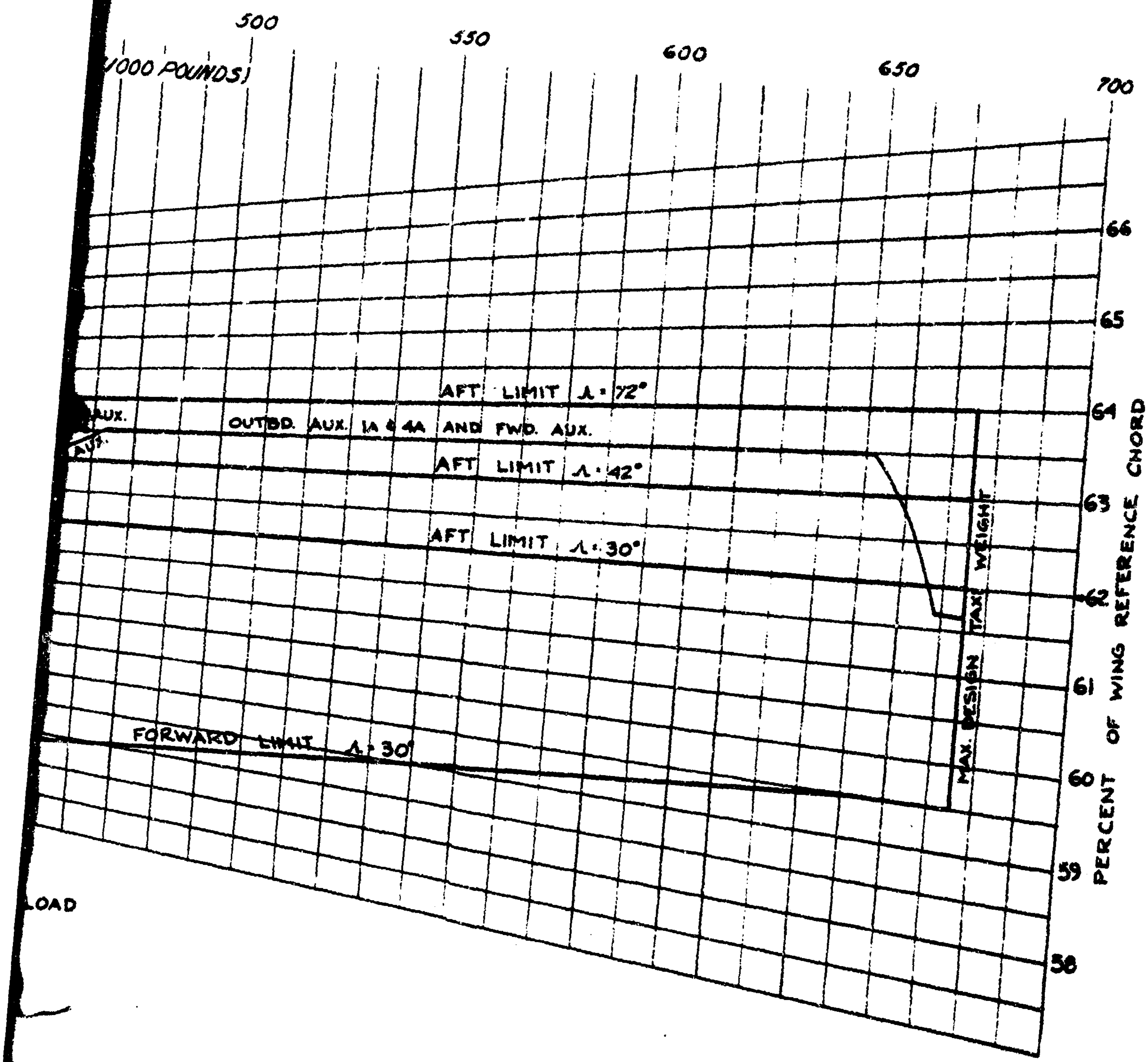
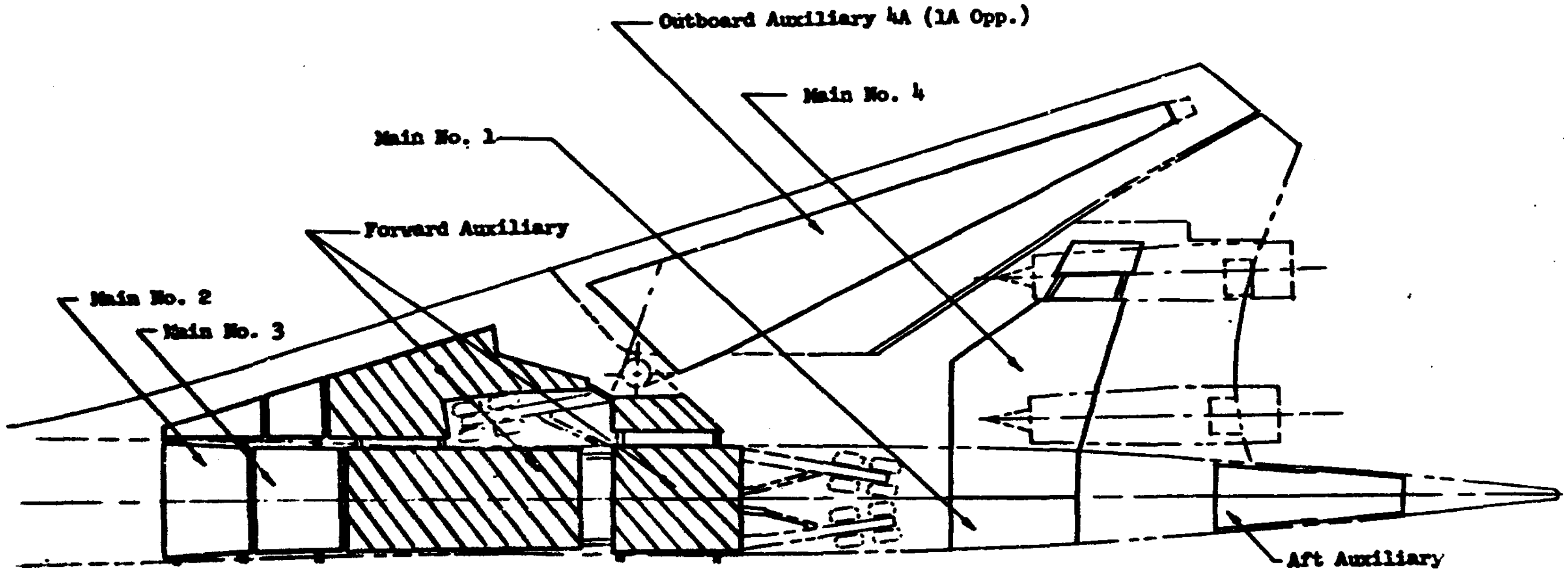


Figure 6. Balance and Loading of the Production Airplane



Tank	Fuel Gallons	Fuel Pounds
Main No. 1	4,150	27,800
Main No. 2	4,150	27,800
Main No. 3	4,150	27,800
Main No. 4	4,150	27,800
Forward Auxiliary	20,450	137,000
Aft Auxiliary	3,820	25,600
Outboard Auxiliary 1A	7,530	50,450
Outboard Auxiliary 4A	7,530	50,450
Total Capacity	55,930	374,700

Note: Maximum Usable Fuel = 367,100 Pounds.

The excess volume in the aft auxiliary is usable at the operator's option to optimize cruise center of gravity for high payloads.

Figure 7. Fuel Tank Arrangement

1002. Design Analysis

10020. DESIGN ANALYSES - GENERAL

Reliability, Maintainability, Safety, Human Engineering, Value Engineering, and Standardization information was provided for 12 trade studies that resulted in the issuance of 11 Design Decision Memoranda (DDM) during this report period.

10024. AERODYNAMIC WIND TUNNEL TESTS

Aerodynamic testing during June and July and proposed through September is shown on the schedule chart, Fig. 8. Wind tunnel occupancy time for Aerodynamics totaled 982 hours during June and July.

	WIND TUNNEL MODEL NUMBER AND DESCRIPTION	JUNE	JULY	AUG	SEPT
LOW SPEED	SA-857 E-10 0.0371 Scale Flap and slat performance for B-2707	UWAL 861			
	SA-857 E-11 0.0371 Scale Wings aft performance and stability for B-2707	UWAL	863		
	SA-981 I-1 0.0367 Scale Sept. 12 FAA/NASA Ames Model				NASA
	SA-967 E-1 0.0367 Scale New, B-2707 Config. Development Model				
	SA-868 M-4 0.055 Scale L.E. Blowing Development Model				
TRANSONIC	SA-841 I-21 0.0164 Scale Preliminary B-2707 stability and control power	BTWT	973		
	SA-856 I-11,-13 0.0274 Scale Transonic and Subsonic Performance of B-2707			BTWT 975 & 980	
	SA-841 I-20 0.0162 Scale Wings aft lateral stability and control of preliminary B-2707	BTWT 981			
	SA-966 I-2 0.0152 Scale Wings aft performance of B-2707				NASA
	SA-984 I-1 0.015 Scale Sept. 6 FAA/NASA Langley Subsonic Model				
	SA-983 I-1 0.015 Scale Sept. 6 FAA/NASA Langley Cruise Model				

Tests Completed | Tests Scheduled

Figure 8 Aerodynamic Wind Tunnel Test Schedule

	WIND TUNNEL MODEL NUMBER AND DESCRIPTION	JUNE	JULY	AUG	SEPT
SUPERSONIC	SA-841 I-21 0.0164 Scale Nacelle pod-wing integration on preliminary B-2707	BSWT	356		
	SA-841 I-20 0.0164 Scale Inlet unstart and engine failure effects on preliminary B-2707	BSWT 357		BSWT 364	
	SA-966 I-1 0.015 Scale Body development for B-2707		BSWT	359	
	SA-841 I-21 0.0164 Scale Engine failure effects on preliminary B-2707		BSWT	361	
	SA-966 I-2 0.0152 Scale Cruise performance of B-2707	BSWT	363		
	SA-977 I-1 0.015 Scale Preliminary performance on advanced B-2707 midwing arrangement	BSWT	365		
	SA-983 I-1 0.015 Scale Sept. 6, FAA/NASA Langley cruise model				NASA
	SA-968 I-1 0.015 Scale New aeroelastic effects model				

Tests Completed | Tests Scheduled

Figure 8. (Concluded)

III. Description of Technical Progress (continued)

10024. Aerodynamic Wind Tunnel Tests (continued)

(1) **Tests Completed**

University of Washington Aeronautical Laboratories (UWAL) Test No. 861, SA-857 E-10, 0.0371 scale. Tested June 23 through July 13. Purpose: To evaluate and determine flap and slat configuration for B-2707; to measure performance and longitudinal control-stability in and out of ground effect.

UWAL Test No. 863, SA-857 E-11, 0.0371 scale. Tested July 19 through 22. Purpose: To evaluate B-2707 low-speed performance with wings aft in and out of ground effect; to measure roll control and lateral-directional stability.

Boeing Transonic Wind Tunnel (BTWT) Test No. 973, SA-841 I-21, 0.0164 scale. Tested June 2 and 3. Purpose: To evaluate wings aft control power and directional stability for preliminary B-2707.

BTWT Test No. 973 and 980, SA-856 I-11, 0.0274 scale. Tested June 16 and 17, June 29 through July 6, July 8 and 9. Purpose: To obtain subsonic and transonic performance and stability data with wings forward and aft on B-2707 configuration.

BTWT Test No. 981, SA-841 I-20, 0.0162 scale. Tested July 6 through 8. Purpose: To determine wings aft, lateral control power and directional stability on B-2707.

Boeing Supersonic Wind Tunnel (BSWT) Test No. 356, SA-841 I-21, 0.0164 scale. Tested June 7 through 10. Purpose: Nacelle pod shape and wing-pod integration on preliminary B-2707.

BSWT Test No. 357, SA-841 I-20, 0.015 scale. Tested June 10 through 15. Purpose: To measure stability and control effects of inlet unstart.

BSWT Test No. 359, SA-966 I-1, 0.015 scale. Tested June 16 through 20 and June 25 through July 1. Purpose: Body size development for B-2707.

BSWT Test No. 361, SA-841 I-21, 0.0164 scale. Tested July 15. Purpose: To evaluate engine failure effects with yaw on preliminary B-2707.

BSWT Test No. 363, SA-966 I-21, 0.0152 scale. Tested July 20 through 22, 24, and 26 through 28. Purpose: To measure cruise performance and tailor B-2707 configuration.

BSWT Test No. 364, SA-841 I-20, 0.0162 scale. Tested July 25. Purpose: To evaluate unyawed engine failure effects and control power on preliminary B-2707.

III. Description of Technical Progress (continued)

10024. Aerodynamic Wind Tunnel Tests (continued)

BSWT Test No. 365, SA-977 I-1, 0.015 scale. Tested July 23. Purpose: Obtain performance data on an advanced B-2707 blended midwing configuration.

(2) Future Test Planning

Three new models for FAA/NASA, simulating the B-2707, are under construction. Flaps-down landing and takeoff configurations will be simulated using SA-981 I-1, subsonic cruise by SA-984 I-1, and supersonic cruise by SA-983 I-1. A new, low-speed development model (SA-967 E-1) is being built, and further high-speed development of a blended midwing (SA-977 I-1) is planned.

1003. Maintainability

The Maintainability unit presently has 40 personnel. Maintainability requirements, determined by the analysis process, are being combined with other system requirements and are being reflected in subsystem specifications and proposal documentation.

10030. GENERAL

The maintainability unit has continued to emphasize the design support effort. Maintenance analysis has been directed primarily to the remove/replace task function of major system components of each subsystem to uncover new maintainability design requirements. In addition to defining airplane design requirements, preliminary task analyses for the remaining maintenance functions of troubleshooting, inspection, servicing, adjustment, calibration, and checkout are being accomplished. The support requirements determined by these analyses include task time, maintenance frequency, maintenance location, number of maintenance personnel, maintenance manhours, and GSE. Maintainability analyses have included data from the maintenance analysis sheets for inputs to the Operational and Maintenance System Simulation Model.

The B-2707 Maintainability Program Plan has been prepared for Phase III. The plan includes a summary of those maintainability activities accomplished during Phase II-C, defines those tasks that will be accomplished during Phase III, and contains a summary of activities to be accomplished during Phases IV and V. The plan will be used to implement Phase III maintainability activities for Boeing and its B-2707 suppliers. The maintainability work statements and engineering manpower estimates for Phase III have been prepared to reflect program plan tasks.

A revision of the Maintenance Design Guide, Commercial Supersonic Transport Document D6-9488 is being prepared to include additional customer maintainability requirements, test and checkout design requirements, and definition of airline terms relating to their operation.

III. Description of Technical Progress (continued)

10031. MAINTAINABILITY ANALYSES

A more detailed quantitative requirements analysis has been completed and the Maintainability Allocations, Document D6A-10264-1, is being updated. Predictions and evaluations based on the time and effort requirements derived from the maintenance analysis are being incorporated in the Predictions and Evaluation, Document D6A-10265-1. Preliminary output data obtained from the system simulation model, such as flight schedules, dispatch reliability, maintenance frequency, time, and availability of support resources, is in the process of being incorporated in the Operations and Maintenance Simulation, Document D6A-10266-1.

All subsystem performance specifications were reviewed for adequacy of maintainability content and change recommendations are being submitted to include additional and updated requirements.

10032. MAINTENANCE ANALYSIS

Detailed determination of maintenance requirements, as described in Par. 10030 are continuing. This analysis includes an identification of remove/replace tasks and task requirements by subsystems. To date, over 1,600 LRU tasks have been identified. Definition and coordination of test and checkout requirements are continuing.

Fifty-six supplier proposals related to 21 equipment procurement items have been reviewed, evaluated for maintainability potential, and ranked during this report period.

10033. MAINTAINABILITY STUDIES

The AIDS feasibility and requirements study is essentially on schedule. Previous subsystem parameters selected as candidates for AIDS monitoring are being updated to conform to the B-2707 design. Airlines and Air Force maintenance data are being analyzed to establish the potential maintenance saving to be realized by the AIDS system. Ground-based and airplane data processing studies pertinent to the operation and utilization of the AIDS are in progress. The objective of these studies is to confirm the adequacy of the computer requirements and to establish additional system requirements. Increased emphasis is being placed on the cost portion of the study so it may be incorporated in the September 6 submittal.

1004. Reliability

10040. RELIABILITY GENERAL

A Quality Program Council has been established with chairmanship vested in the Assistant Program Director, Program Management. The purpose of the council is to evaluate, coordinate, and direct SST Division efforts in order to achieve high quality in all aspects of the program. Its membership consists of principal organization heads in Engineering, Operations, Quality Control, and Program Planning and Integration. Other organizations will participate as requested.

Reliability program management responsibilities have been assigned to Engineering and will be carried out by the reliability unit supervisor, who will act as Reliability Manager.

<u>Mathematical Models</u>

An Automatic Reliability Mathematical Model (ARMM) has been programed on the IBM 7094 computer and is being used to analyze subsystem and airplane inflight reliability. Initial results have been obtained for each subsystem and for the airplane. In addition, the ARMM is being used to prepare inputs for a newly developed Fleet Integrated Reliability Mathematical Model (FIRMM).

Initial development of the FIRMM has been completed this period. It will be used to assess fleet-wide departure and fleet-wide inflight reliability by simulating operation of a typical airline fleet.

10041. RELIABILITY DESIGN SUPPORT

The following documents have been released during the reporting period:

D6A10064-2 - Reliability Analysis Document—Accessory Drive & Engine Starting Subsystem
D6A10064-3 - Reliability Analysis Document—Aircraft Integrated Data System

III. Description of Technical Progress (continued)

10041. Reliability Design Support (continued)

D6A10064-5 - Reliability Analysis Document—Communications Subsystem
D6A10064-8 - Reliability Analysis Document—Flight Controls Subsystem
D6A10064-12 - Reliability Analysis Document—Navigation & Flight Instruments Subsystem

Subsystem specifications drafts have been reviewed and reliability inputs provided.

One hundred and eight-five supplier proposals related to 53 equipment procurement items have been reviewed, evaluated for reliability potential, and ranked.

10042. RELIABILITY ANALYSIS

A revised Failure/Error Mode, Effect, and Criticality analysis form and instruction has been approved and released. The form is currently in use by the project designers.

A system level Failure/Error Mode, Effect, and Criticality analysis is 75 percent complete.

A preliminary Minimum Equipment List has been completed.

Preliminary reliability allocations were revised to agree with the subsystem breakdown at Level 3 of the Work Breakdown Structure.

Work has been progressing on recording information on a reliability engineering test control log. Test plan information is being obtained from the Test Plan Summaries and the Engineering Work Authorizations.

10044. DESIGN SUPPORT DATA CENTRAL

During the months of June and July, the Design Support Data Central has continued to collect, index, file, analyze, and disseminate airplane service data in support of reliability, maintainability, and safety analyses. Preliminary distribution was made of the Design Support Data Index and the Reliability and Maintainability Prediction Standards documents. These documents are being revised periodically to keep abreast of new data acquired and analyses completed. Maintenance cost data have recently been received from several airlines and are being analyzed for incorporation in the prediction standards document in a later revision.

III. Description of Technical Progress (continued)

10044. Design Support Data Central (continued)

Actuarial analyses have been performed using current airline data to test the actuarial computer programs being developed for SST. The Data Central has also participated in a program-wide trade study of electronic data processing systems to serve the entire SST Division.

Analysis of 727 service problems for all ATA Systems has been completed and disseminated. The analysis includes flight deviation, cancellation, and delay rates and causes. Flight reliability data has been received for the 707-320 airplane to be incorporated in similar analyses.

Data Central planning activities have continued toward the development of a data system plan to be available at the on-site inspection in September. Planning effort has been applied to support documentation such as the Product Assurance, Quality Control, Systems Test, and Data Management Proposals. A draft of the Failure Reporting and Corrective Action System document, D6A10245-2, was completed and disseminated to support the proposal effort. Operating procedures relating to the corrective action system for Phase III are being reviewed and revised as applicable.

The total manpower applied to the Design Support Data Central effort reached a peak of 23 in mid-July. This includes the addition of six people since the May Report.

1007. Product and System Safety

10070. SAFETY GENERAL

The Safety Unit was increased to 27 people, including personnel with substantial experience from supersonic military airplane programs.

10071. DESIGN SUPPORT

Safety evaluation of 56 supplier proposals on 21 related equipment procurement items was accomplished during the report period. The evaluations considered safety program management and safety features in the proposed designs and ranked the suppliers as appropriate.

A technique was developed for locating redundant equipment, lines, and wiring to preclude any engine burst failure from damaging both the primary and redundant elements of the system. Use of the technique will be particularly beneficial to safety when locating critical equipment, plumbing, or wiring in the fuselage area lying within the tangential spray pattern area defined by the location of the engine turbine and compressor.

10071. Design Support (continued)

Safety criteria were established for locating the electrical power supply and distribution equipment in the airplane. The criteria are based largely on the fundamental concepts that ignition sources should be sealed from combustible material and generally located:

(1) As high in the airplane as possible

(2) Forward of all fuel tanks

(3) Such that power cables are as short as possible.

The fault tree analysis program was implemented during this report period. The "undesired event" has been established as - "Major damage to the airplane or injury to personnel." The first branch of the tree covered loss of thrust due to fuel system malfunctions. Additional branches are in work.

Operational safety analyses of the entire airplane were continued, and the results of these analyses were used to establish safety requirements for each subsystem area of the airplane.

In addition, the Safety Unit participated in design reviews, a visibility evaluation of the cockpit simulator, and trade studies of the movable nose section, fuel boost pumps, hydraulic reservoir, and engine throttles.

1008. Materials and Processes

Thermal Acoustical Insulation

A preliminary material specification (XBMS 9-6), which defines the requirements and tests for thermal-acoustical fiberglass insulation for temperature service to 550°F was released for coordination.

Integral Fuel Tank Insulation

A 31- by 10-in. panel coated with a fluorinated elastomer was subjected to 100,000 cycles of tension-compression loading at 450°F without failure of the insulation material. The test panel is representative of outboard wing structure. Prior to loading, the insulation was exposed to aging in fuel at 250°F and in a nitrogen-fuel vapor mixture at 400°F. Loads were 31,200 psi in tension and 8,800 psi in compression. An additional 150 limit loads of 62,000 psi were applied. Completion of this work fulfills all high-temperature testing objectives of the program.

An identical insulated panel now in test has been subjected to 40,000 loading cycles at -65°F. Tension loads are 38,200 psi and compression loads are 10,700 psi. To date, an additional 30 limit loads

III. Description of Technical Progress (continued)

1008. Materials and Processes (continued)

of 76,000 psi have been applied. The insulation on this panel was also exposed to the fuel- and heat-aging previously described. Such aging is again in progress and will take place after each 20,000 loading cycles. A total of 100,000 loading cycles, plus an additional 150 limit loads, is again the objective.

Fuel Containment

A test plate sealed with Dow Corning 94-002 fluorosilicone fillet sealant did not leak after 5,000 hours of cyclic fuel and heat exposure and 180 shear-loading cycles. A second test plate sealed with Dow Corning 94-508 fluorosilicone faying surface sealant (no acetic acid generated) did not leak after 2500 hours of cyclic fuel and heat exposure and 120 shear-loading cycles. These test plates are undergoing additional environmental cycling.

Additional test plates are being sealed with Dow Corning 94-002 and 94-512 (an improved version of 94-508) for cyclic exposure at a higher temperature. Presently, the test plates are alternately exposed to JP-5 fuel at 250°F and to a nitrogen-fuel vapor mixture at 400°F. The new cyclic exposure schedule will call for an increase in the temperature of the nitrogen-fuel vapor mixture to 450°F. The following sealants will be tested using both cyclic exposure temperatures: Dow Corning 94-512, 3M XA 5407, and an Air Force Materials Laboratory Viton formulation.

Fuel Seals

Three O-ring and three Gask-O-Seal configurations have completed 480 hours of alternate exposure to JP-5 fuel at 250°F, and to air at 475°F, with no evidence of leakage. Testing for leakage was performed at -40°F with 10 psig pressure. The O-rings were Parker V361-7 Viton, Parker 77-545 Viton, and Hadbar 1000-80 fluorosilicone. The Gask-O-Seals were Stillman SR 276-70 Viton, Parker 77-545 Viton, and Parker L610-8 fluorosilicone.

Conducting Coatings

Elevated-temperature-resistant coatings with surface electrical resistances in the range of 10 to 100 megohms per square are desired for dissipation of static charges in radome applications where high rf transparency is required. No commercial source of paint for this purpose has been found. In-house formulation involving additions of carbon black to Dow Corning 92-009 silastic dispersion have been tested. Results are shown in Fig. 9. Selection of the appropriate composition is made through extrapolation of this additive versus resistance curve. A test program has been initiated to evaluate the long-term properties of this coating in the B-2707 environment.

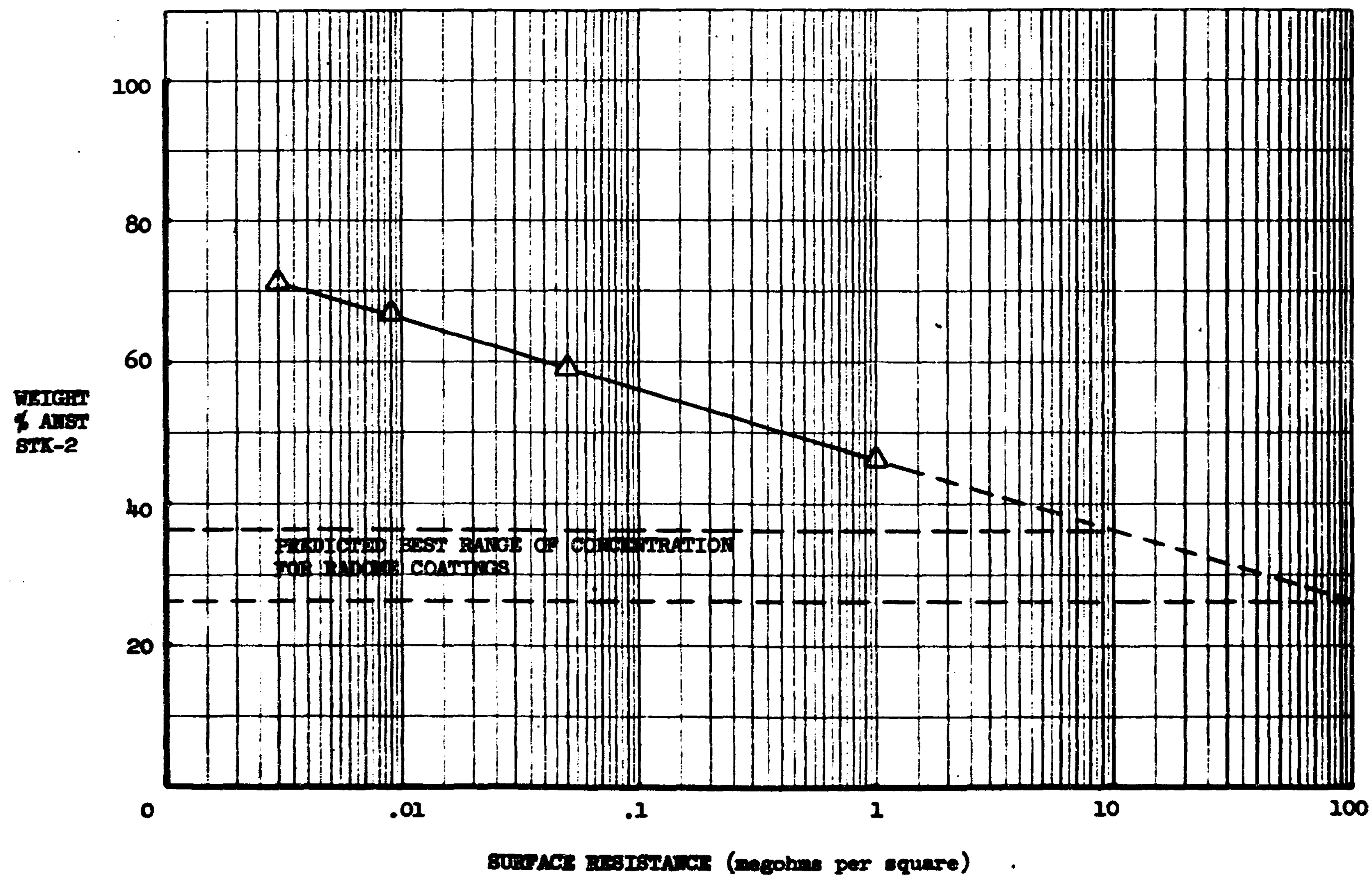


Figure 9. The Influence of Conductive Pigment Concentration on the Surface Resistance of Anti-Static Coating Formulations

III. Description of Technical Progress (continued)

1008. Materials and Processes (continued)

Materials Compatibility

Five fuel sealants (94-002, 94-023, 94-512, EC 2332, and AFML Viton), two pressure sealants (RTV-60 and RTV 106), and three aerodynamic smoothers (RTV 1071, RTV 1072, and CA-9R) were screened for compatibility with titanium alloy Ti 8Al-1Mo-1V. The modified Langley Research Center test for stress corrosion was made using this alloy in contact with these materials at 450°F for a period of 168 hours. Additional tests were made in boiling water for a period of 72 hours.

AFML Viton was found to markedly reduce the bend characteristics of the alloy after elevated temperature exposure. The remaining materials caused only slight (less than 10 percent from the average) reduction in bend at failure.

Fatigue testing of specimens coated with the 94-002 sealant is nearing completion. The base metal S/N curves have been established for standard and notched specimens.

Manufacturing Aids

Additional manufacturing aid materials have been checked for compatibility with titanium alloys and with materials approved for manufacturing use. These include:

Spraylat SC-1071	Temporary protective coatings
Turco 4316	Heat treat scale conditioner
Solvac N.P.	Cutting oil
Solvac 2032	Cutting oil
DTE 24	Hydraulic oil
Mist Lube 63	Lubricant
BAC 24	Way lubricant

Laminate Sealing

Additional diffusion tests to EC 1937-coated polyimide laminate panels were conducted under refluxing conditions using water and JP-5 fuel as test fluids at temperatures of 215°F and 250°F, respectively. Polyimide laminate panels, coated with EC 1937 to a thickness of 6 mils, were first tested for 9 days for water permeability. The test fluid was then replaced with JP-5 fuel and the test continued for another 9 days. Figure 10 shows the results of these tests; a comparable leakage was obtained for both fluids.

Also evaluated under the same conditions was a 3M material coded PA 2758. Although the coating thickness was 10 mils, a higher leakage was obtained. This material has been eliminated from further testing. Other candidate materials currently under evaluation include Dow Corning silicone resins and Monsanto polyimide resins.

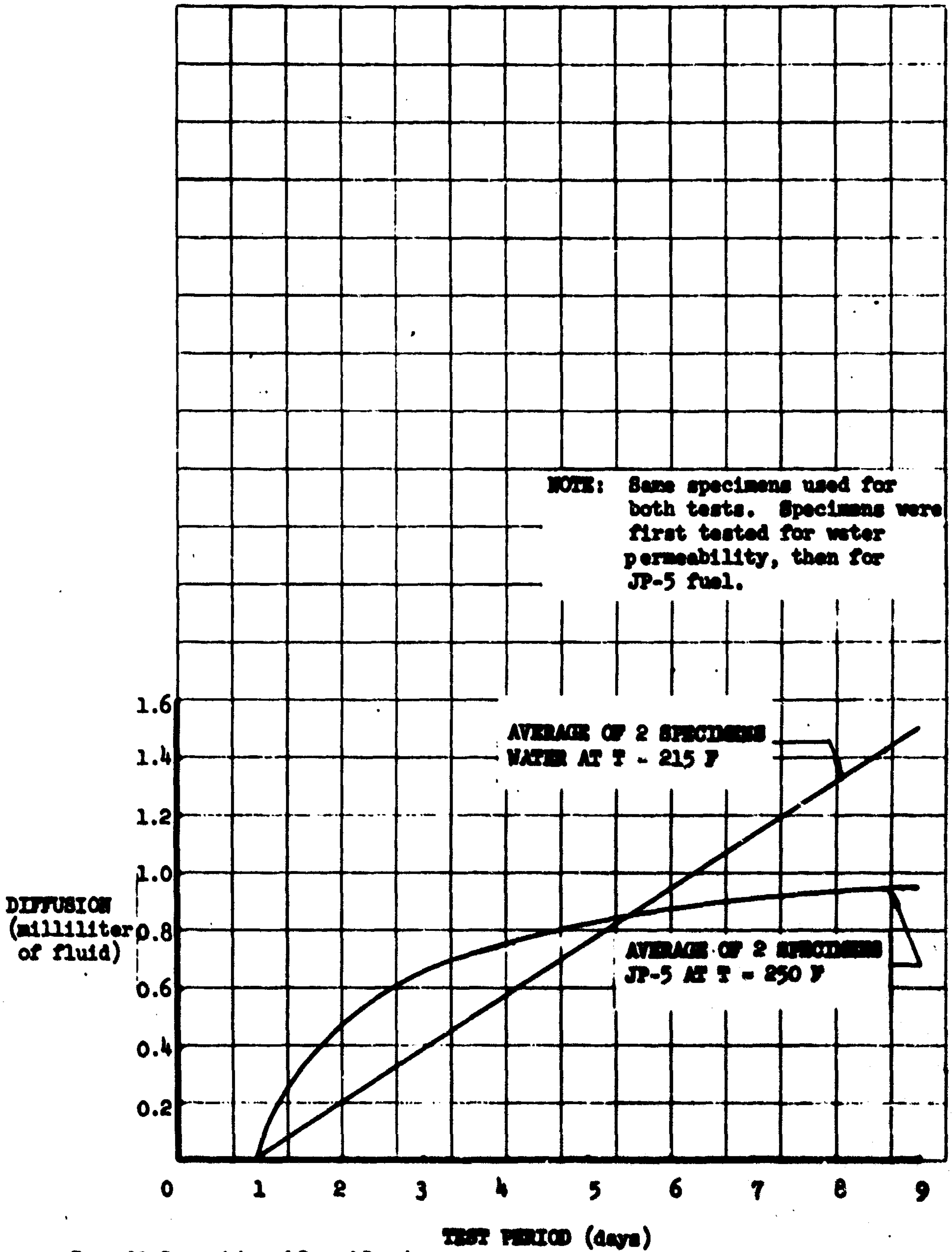


Figure 10. Permeability of Coated Panels

Evaluation of Extreme-Temperature Greases

Oscillating bearing tests were run on an AN 200 K5, shielded, 440 stainless steel bearing at 450°F with a 1405-lb radial load (25 percent of bearing rated capacity) at ±30 degrees oscillation with Marlin Rockwell EG 551 grease as the lubricant. The first test was terminated after 18,000 cycles, or 10 hours of testing, due to equipment failure. The bearing and EG 551 grease appeared to be in serviceable condition and capable of further service.

A new bearing was lubricated with new Marlin Rockwell EG 551 grease, and the test rerun. The second test ran for 75 hours for a total of 100,700 cycles. Failure of the bearing was attributed to bleeding and thermal decomposition of the grease fluid which resulted in high torque and scoring of the bearing balls and races.

Another bearing lubricated with DuPont PR 204AC grease has accumulated 60 hours of running time to date and testing will be continued until failure of the bearing occurs.

Solid-Film Lubricant Evaluation for Galling Protection of Titanium and Journal Bearing Applications

Three solid-film lubricants have been evaluated for friction and wear life when applied to 6Al-4V titanium specimens and tested at 450°F under a 200-psi load. Results of tests on these lubricant coatings are given in Table III and are discussed below:

(1) MRL-1

This bonded solid-film is an experimental product developed by the Midwest Research Laboratories and is composed of MoS_2 and an unidentified solid lubricating pigment dispersed in a high-temperature resin binder. Wear life of this coating at 450°F at a 200-psi load averaged 240,000 reciprocating cycles (15,840 ft of travel) for two tests, and the average coefficient of friction was less than 0.08. This wear life is 200 percent greater than that of any other coating tested under these conditions.

Wear life of the MRL-1 coating at 450°F and 10,000-psi load was also determined when applied to 440-C and 17-7PH steel specimens. The average wear life was 17,000 cycles (2,833 ft of travel), which ranks it as the third best coating evaluated under these conditions. The average wear life found for the Vitrolube and Everlube 811 solid-film lubricants was reported earlier to be 83,000 cycles and 19,000 cycles, respectively.

Results obtained with the MRL-1 lubricant coating is considered encouraging, and additional testing is planned on other modifications which are reported to have greater load carrying capacity.

Table III. Wear Lives of Anti-Galling Lubricant Coating for Titanium (450°F and 200 psi Load)

Lubricant	Vendor	Binder Type	Lubricant Pigments	Wear Life*		Remarks
				Cycles (reciprocating)	Feet	
Lubeco 2123	Lubeco, Inc.	Phosphate	MoS_2, Graphite, PbS	12,699	836	Specimens pre-treated by grit blasting
Lubeco 2123	Lubeco Inc. + Watervliet Arsenal.	Phosphate	MoS_2, Graphite, PbS	12,399	816	Specimens pre-treated with Lubeco hard anodize
Lubeco 2123	Lubeco, Inc.	Phosphate	MoS_2, Graphite, PbS	16,995	1,120	Specimens pre-treated with Watervliet Hardcoat
Surf-Kote	Hohman Pltng. and Mfg.	Metal Matrix, Resin Bonded	MoS_2, ?	81,921	5,400	Applied by vendor - tested by Boeing
Surf-Kote	Hohman Pltng. and Mfg.	Metal Matrix, Resin Bonded	MoS_2, ?	32,598	2,150	Applied by Boeing - tested by Boeing
MRL -1	Midwest Research Institute	Unknown	MoS_2 ?	240,000	15,840	Experimental coating

*Average of Two Tests

III. Description of Technical Progress (continued)

1008. Materials and Processes (continued)

(2) Surf-Kote M-1840

Surf-Kote M-1840 is a metal matrix resin-bonded MoS_2 lubricant manufactured by the Hohman Plating and Manufacturing Company. Evaluation of this coating consisted of two tests, each using 6Al-4V titanium specimens coated by the vendor and by Boeing. The average wear life of vendor-coated specimens was 81,921 cycles (5,[illegible]0 ft of travel) and the wear life of the Boeing coated specimens was 32,598 cycles (2,150 ft of travel). The reasons for reduced wear life of the Boeing-coated specimens is not known, but processing, testing, or other variables which may affect the wear life of this coating are being investigated.

(3) Lubeco 2123

This coating, supplied by Lubeco, Inc. consists of MoS_2, graphite, and PbS dispersed in an inorganic phosphate binder. Wear life of this coating when applied to grit-blasted 6Al-4V titanium specimens (reported in the May Progress Report) is 12,699 cycles (836 ft of travel). Wear life of Lubeco 2123 applied over 6Al-4V titanium specimens pretreated with hard-anodized processes (available from Lubeco and Watervliet Arsenal) has been found to be 12,399 cycles (816 ft of travel) and 16,995 cycles (1,120 ft of travel), respectively. The purpose of these tests was to compare grit blasting with hard-anodizing titanium pretreatments on the wear life of Lubeco 2123. It appears from these tests that there is very little difference between the two methods of pretreating titanium with respect to wear life of the Lubeco 2123 solid-film lubricant.

Evaluation of Self-Lubricating, Movable-Seal Compact and Rub Strip Materials

Wear-resistance evaluations of Boeing lubricant compact number 180-67 (used as the movable seal material in the engine inlet centerbody) and Rulon LD have been conducted at 450°F and 535°F under a 200-psi load with reciprocating motion. Wear rates determined in these evaluations are indicated in Table IV and are shown graphically in Fig. 11.

Table IV. Wear Rates of Boeing Lubricant Compact No. 108–67 and Rulon LD at 200 psi Load

Test duration	Temp, °F	Wear rate, in/ft of travel	
		Boeing Compact No. 108-67	Rulon LD
0 to 50,000 Cycles	450	2.3×10^{-7}	12.5×10^{-7}
50,000 to 100,000 Cycles	450	1.3×10^{-7}	5.3×10^{-7}
0 to 50,000 Cycles	535	3.7×10^{-7}	13.2×10^{-7}
50,000 to 100,000 Cycles	535	2.8×10^{-7}	4.1×10^{-7}

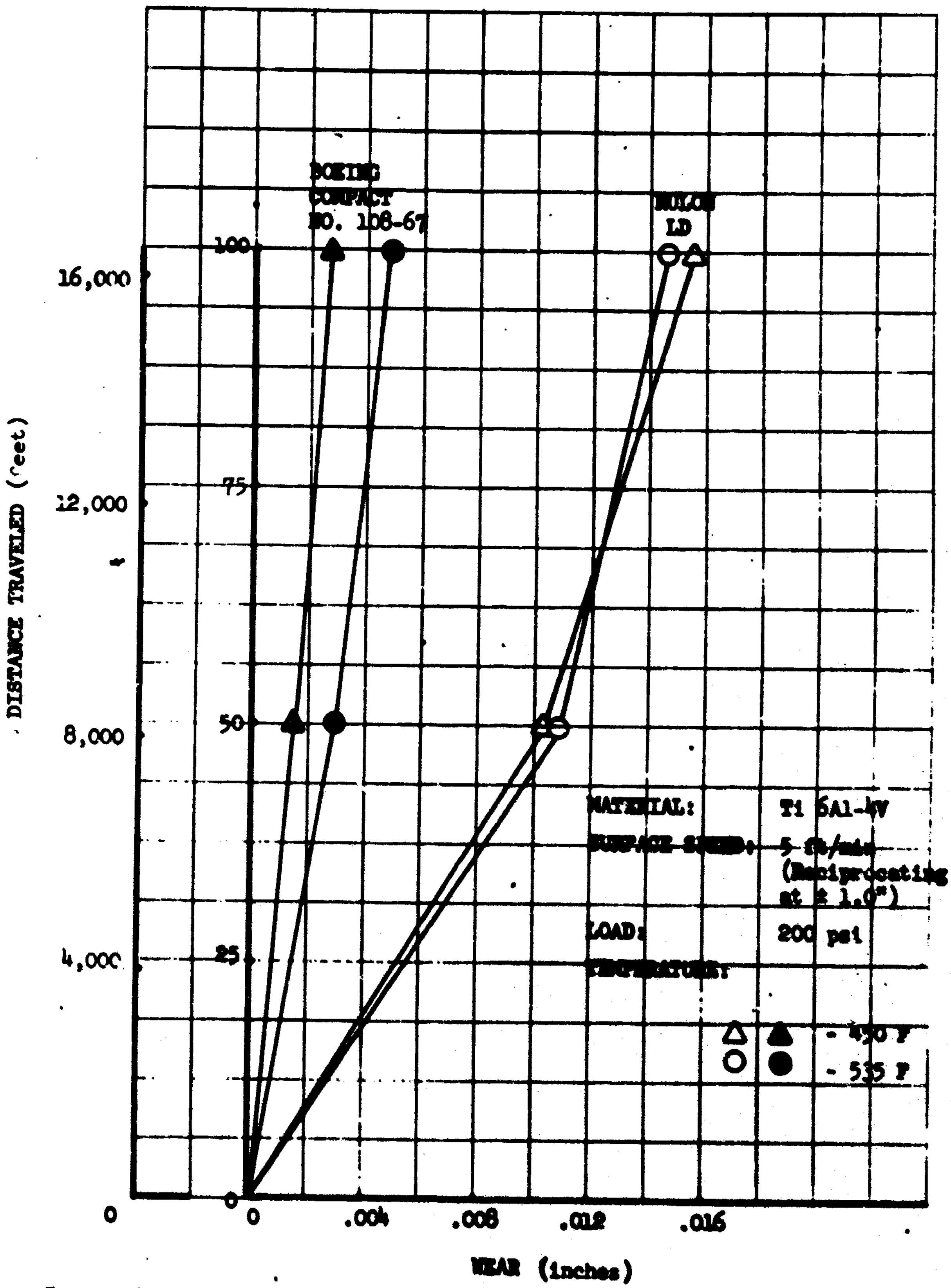


Figure 11. Wear Rate of Boeing-Developed Compact No. 108-67 and Rulon LD

The data indicated that the Boeing Compact number 108-67 has superior wear resistance. Initial wear rate (i.e., 0 to 50,000 cycles) is much greater for both materials than the final wear rate (i.e., 50,000 to 100,000 cycles) due to initial 'wear-in' necessary to form a transfer film to the mating 6Al-4V titanium surface. Further, note that comparative differences in wear rates of these two materials during the final 50,000 cycles of the test is not as great as it was during the first 50,000 cycles. This is shown by the same general slope of the wear rate curves during the 50,000- to 100,000-cycle period.

Other Boeing lubricant compact materials have been developed which show compressive strengths of 190,000 psi with wear rates of as low as 5×10^{-7} in./ft of travel under a 10,000-psi load. With self-lubricating material having these strengths and low-wear properties, the life expectancy of journal bearings and track sliders may be extended significantly.

Hydraulic System Seals

A laboratory test program is being conducted to evaluate the compatibility of candidate seal materials and hydraulic fluids. Environmental screening of the seal materials is also in progress. The first series of material-fluid compatibility tests have been completed with the results displayed as bar graphs, Figs. 12 through 17.

The material-fluid compatibility tests were set up to screen fluid-material pairs at +430°F for 7 days. Previous tests had established the superiority of the fluorocarbons over the silicones and fluorosilicones. Six fluorocarbons were tested in three different hydraulic fluids to establish a complete picture of fluid and material relationships. The necessity for testing different fluorocarbons results from the fact that the Viton formulations prepared by different suppliers exhibit different properties. Results from these tests clearly demonstrate the superiority of the Parker 77-545 formulation over the other fluorocarbons in all of the hydraulic fluids. The Dow-Corning XF1-0294 hydraulic fluid exhibited the greatest compatibility with all of the materials tested. Three of the fluorocarbons are usable only in the XF1-0294 fluid at the temperatures typical of the hydraulic system environment.

A new material representative of the SiB elastomer family is being tested with favorable results in the XF1-0294 fluid at 500°F. The poly-m-carboronylsiloxane material was found to be compatible only with the Dow-Corning XF1-0294 fluid.

Polyimide Laminates

Processing of polyimide laminates 0.125 in. thick, or thicker, allows 20 percent of the plies to be dry fabric. The excess resin is

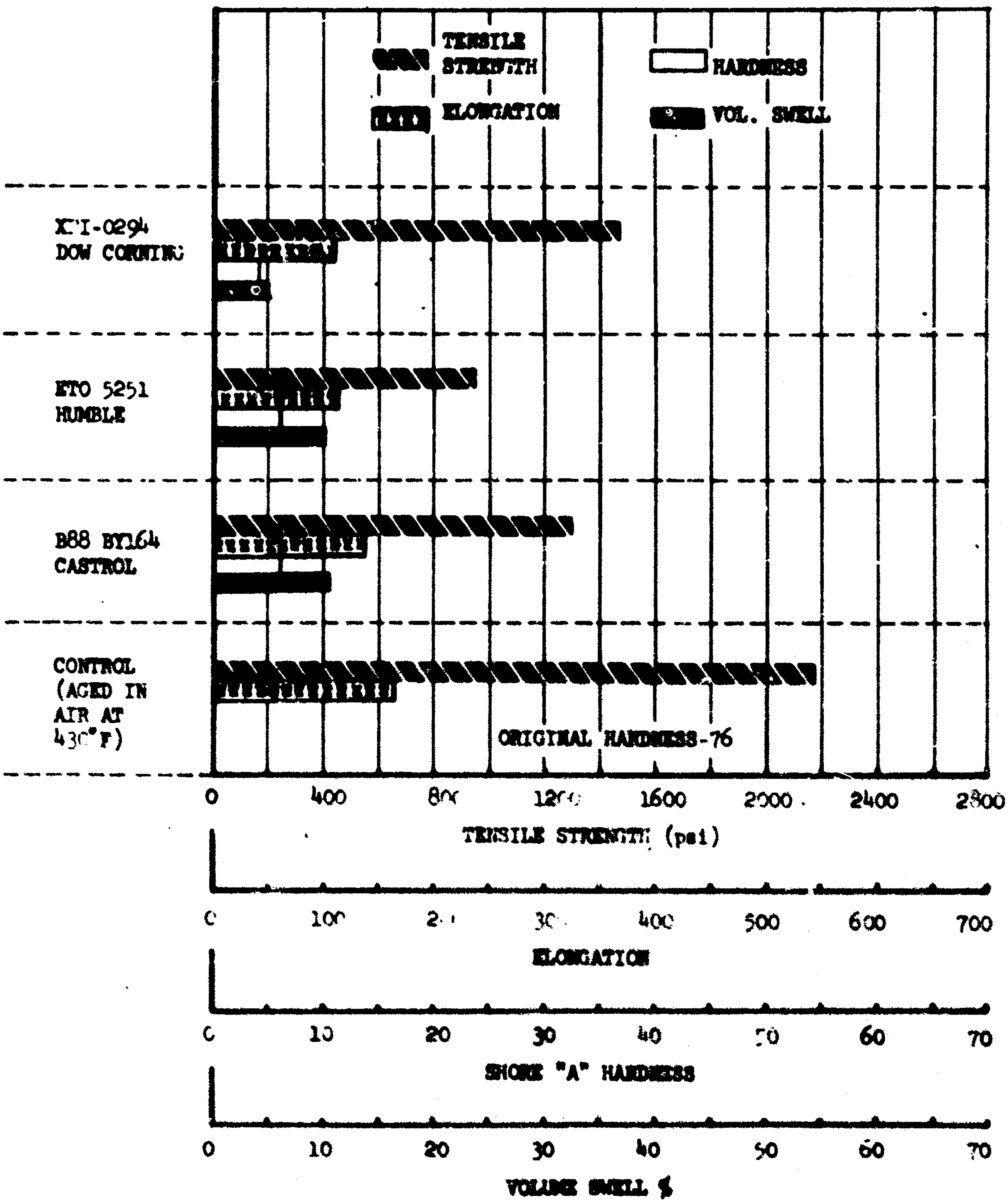


Figure 12. Fluorocarbon (Stillman SR-276-70) Compound Compatibility (7 days in fluid at 430° F)

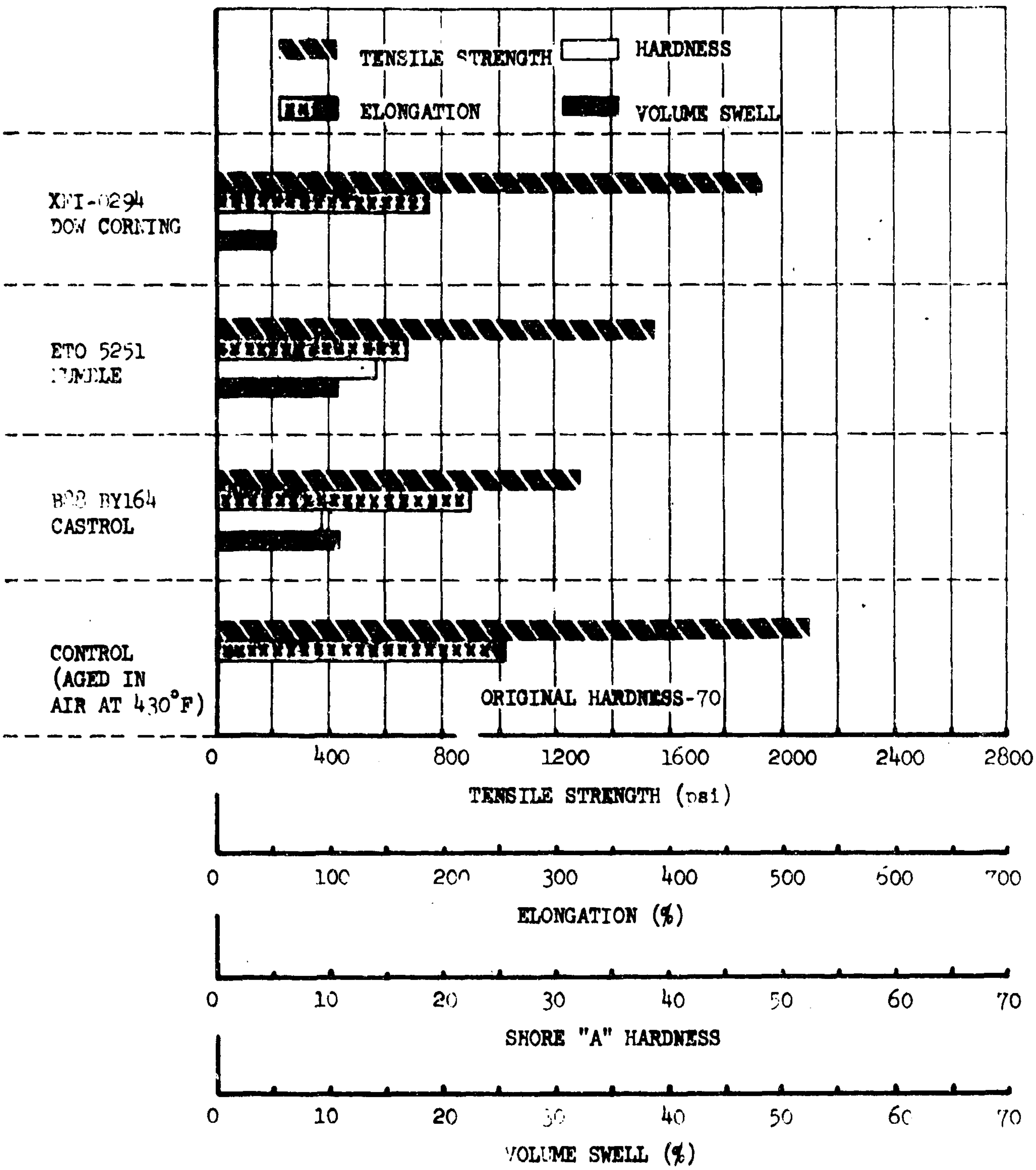


Figure 13. Fluorocarbon (Parker 77-545, Viton) Compound Compatibility (7 days in fluid at 430°F)

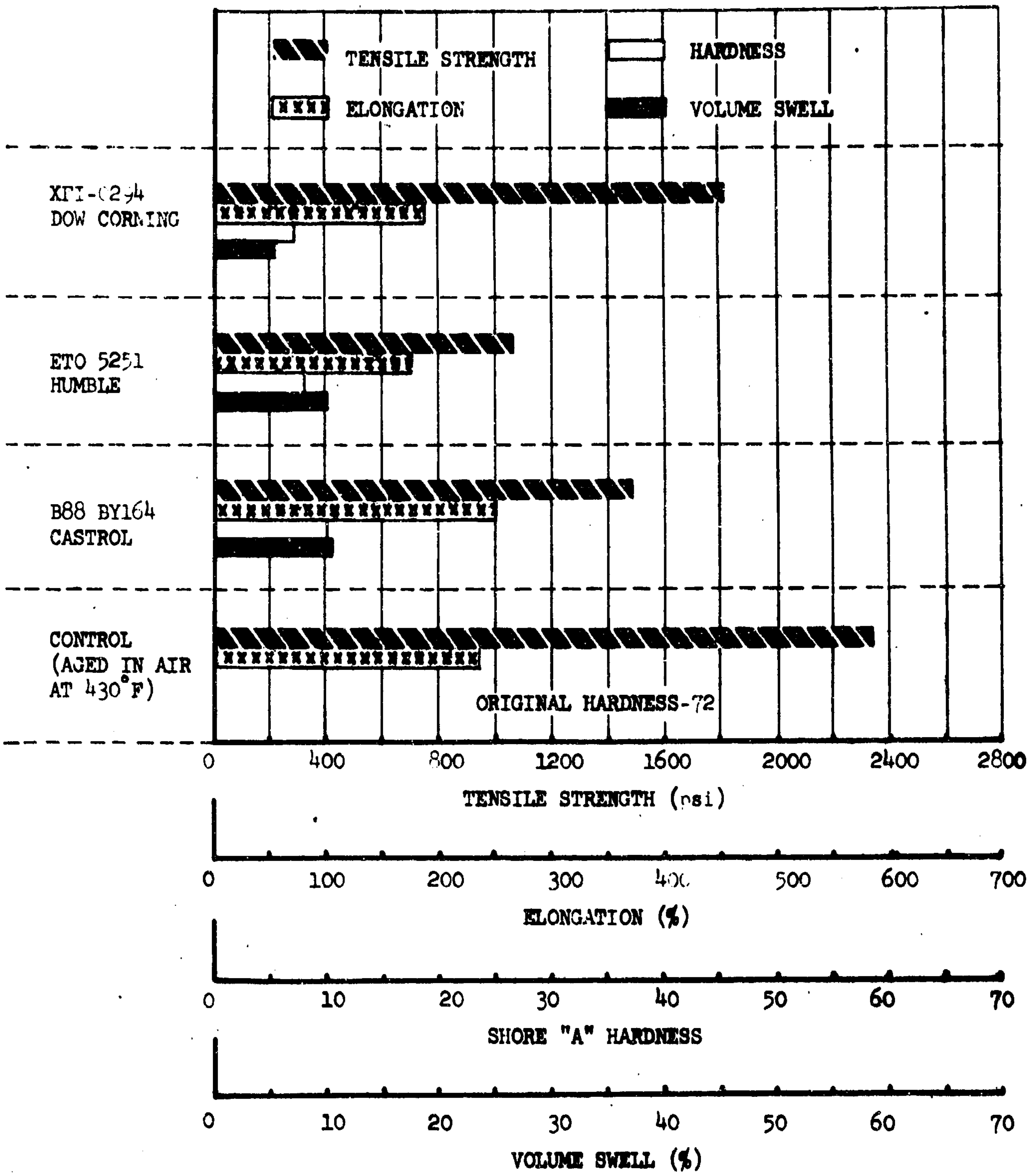


Figure 14. Flurocarbon (Parker V–361–7) Compound Compatibility (7 days in fluid at 430°F)

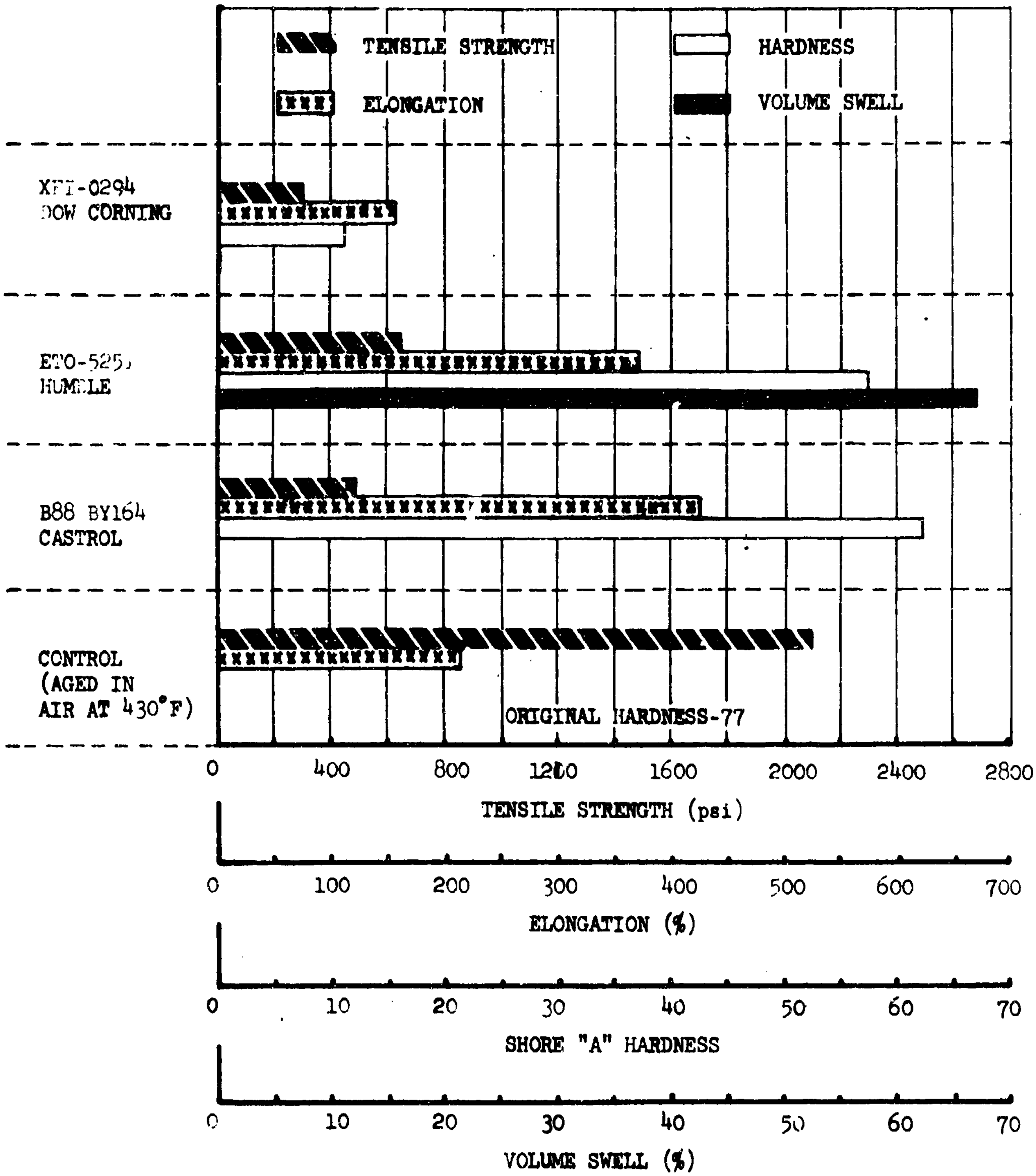


Figure 15. Compound Compatibility (Parker 515-8) (7 days in fluid at 430°F)

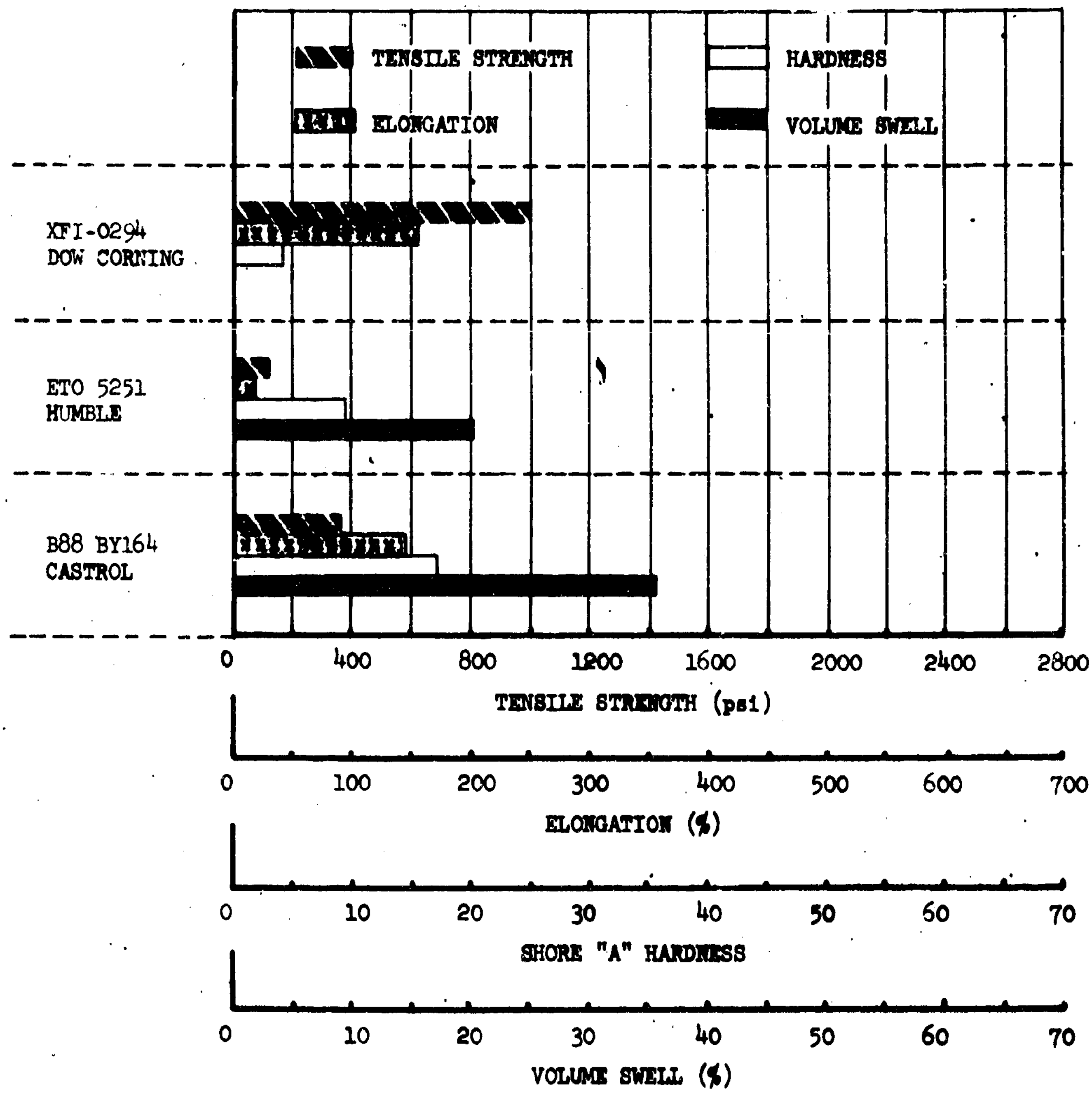


Figure 16. David Clark X-FVF-4A Compound Compatibility (7 days in fluid at 430°F)

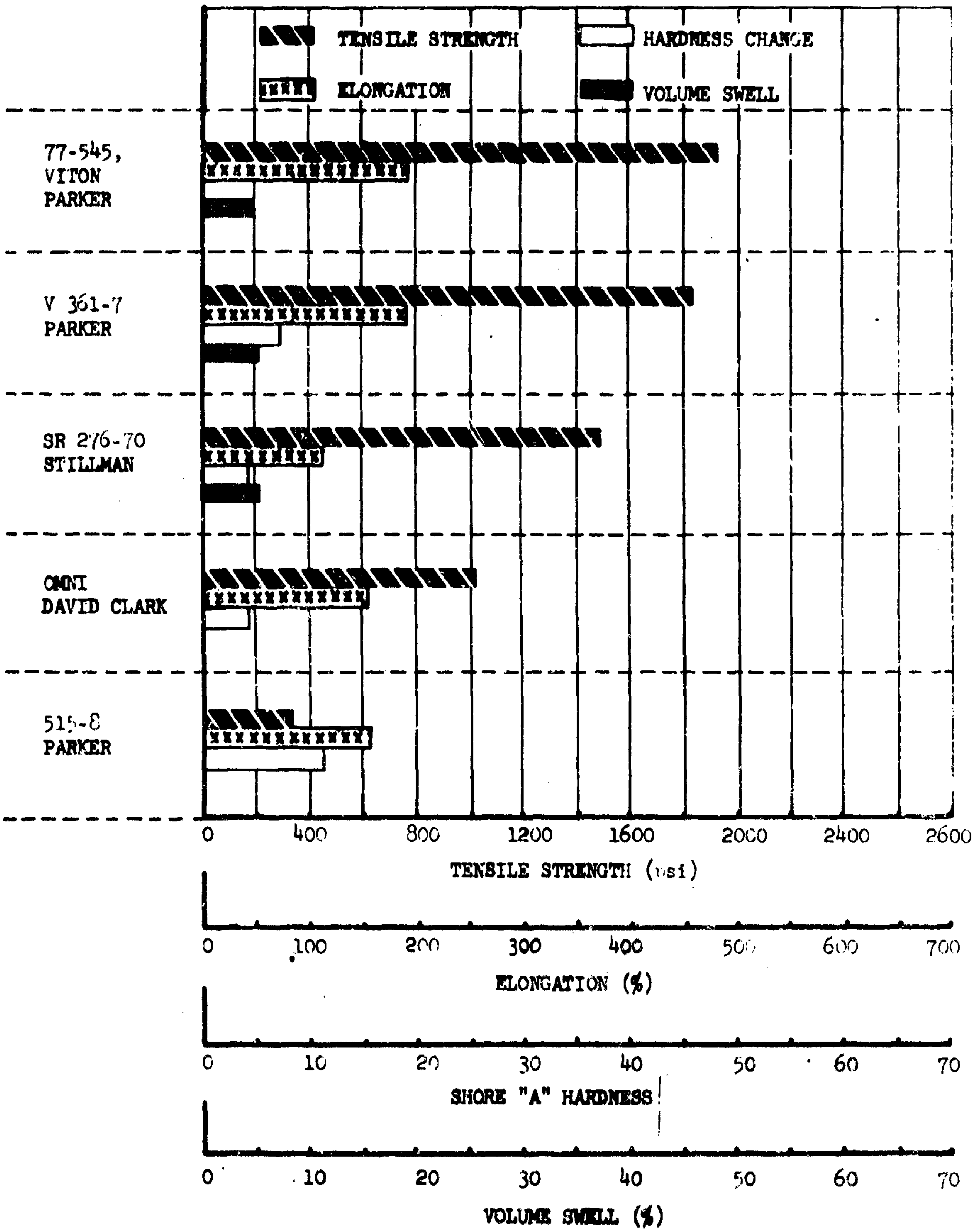


Figure 17. Fluorocarbon Compound XFI-0294 Hydraulic Fluid (7 days at 430°F)

taken up uniformly in the dry fabric, and allows for volatile escapement that is required to make a second laminate. The ability to reduce the raw material prepreg used in the laminate also reduces the material cost to the level of phenolic and epoxy systems. Table V gives the physical and mechanical properties of a Skybond 700 polyimide laminate fabricated in excess of 1 in. in thickness, where every fifth ply was a dry-fabric ply Style 181 'E' glass.

Table V Polyimide Vacuum Bag Autoclave Physical Property Data for Thick Laminate

Panel area	Resin content (%)	Specific gravity	Interlaminar shear, strength avg (psi)	Interlaminar shear after 3-hour water boil, avg (psi)
Top	23.9	1.59	2324	1860
Center	23.6	1.58	2360	2272
Bottom	22.9	1.61	2390	2108

*Panel thickness 1.11 in. 93 plies XBMS 8-123 prepreg plus 23 plies dry fabric, every 5th ply.

**All values shown are the average of 4 or more specimens.

Narmco 1830 Polyimide Prepreg on "E" Glass

Improved mechanical properties strengths have been received from tests on Narmco 1830 polyimide resin on Style 181 'E' glass reinforcement. Tests were completed after 1000 hours aging at 400° and 550°F. Table VI shows the mechanical properties obtained, while Figs. 18, 19, and 20 show the comparative values between Skybond 700 and 1830 under similar processing.

The 9,000-hour aging tests are presented in Figs. 21 through 26. An analysis of these curves indicates that thermal stability has been achieved and very little degradation can be expected with further aging.

Polyimide Laminate Properties

The following values were determined for the coefficient of linear thermal expansion of an 'S' glass-reinforced Skybond 700 polyimide resin laminate:

$$\text{Warp } -2.37 \times 10^{-6} \frac{\text{in.}}{\text{in.}^\circ\text{F}}$$

$$\text{fill} = 2.62 \times 10^{-6} \frac{\text{in.}}{\text{in.}^\circ\text{F}}$$

Table VI. NARMCO 1830

Conditioning		Tensile Properties		Compression Properties		Flexure Properties		Interlaminate Shear	
Test Temp	Hours @ 550°F	Strength (ksi)	Modulus (psi x 10^6)	Strength (ksi)	Modulus (psi x 10^6)	Strength (ksi)	Modulus (psi x 10^6)	As Received	3-Hour Water Boil
Room	0	59.36	4.75	50.18	4.20	68.27	3.38	Tests not Complete	
550°F	0	32.58	3.85	22.65	2.91	26.49	2.14		
Room	1000	38.61	3.76	31.61	4.08	42.12	2.65		
550°F	1000	38.36	3.08	27.73	3.40	33.06	2.22		
	Age 400°F								
Room	1000	55.88	3.98	47.42	4.36	63.50	3.03		

MATERIAL/PROPERTIES - NARMCO 1830, Batch 1, Roll 1

Resin Content - 33.5%
Volatiles - 8.5%
Flow - 24.4%
Gel Time -280 seconds

NARMCO 1830 Polyimide Prepreg

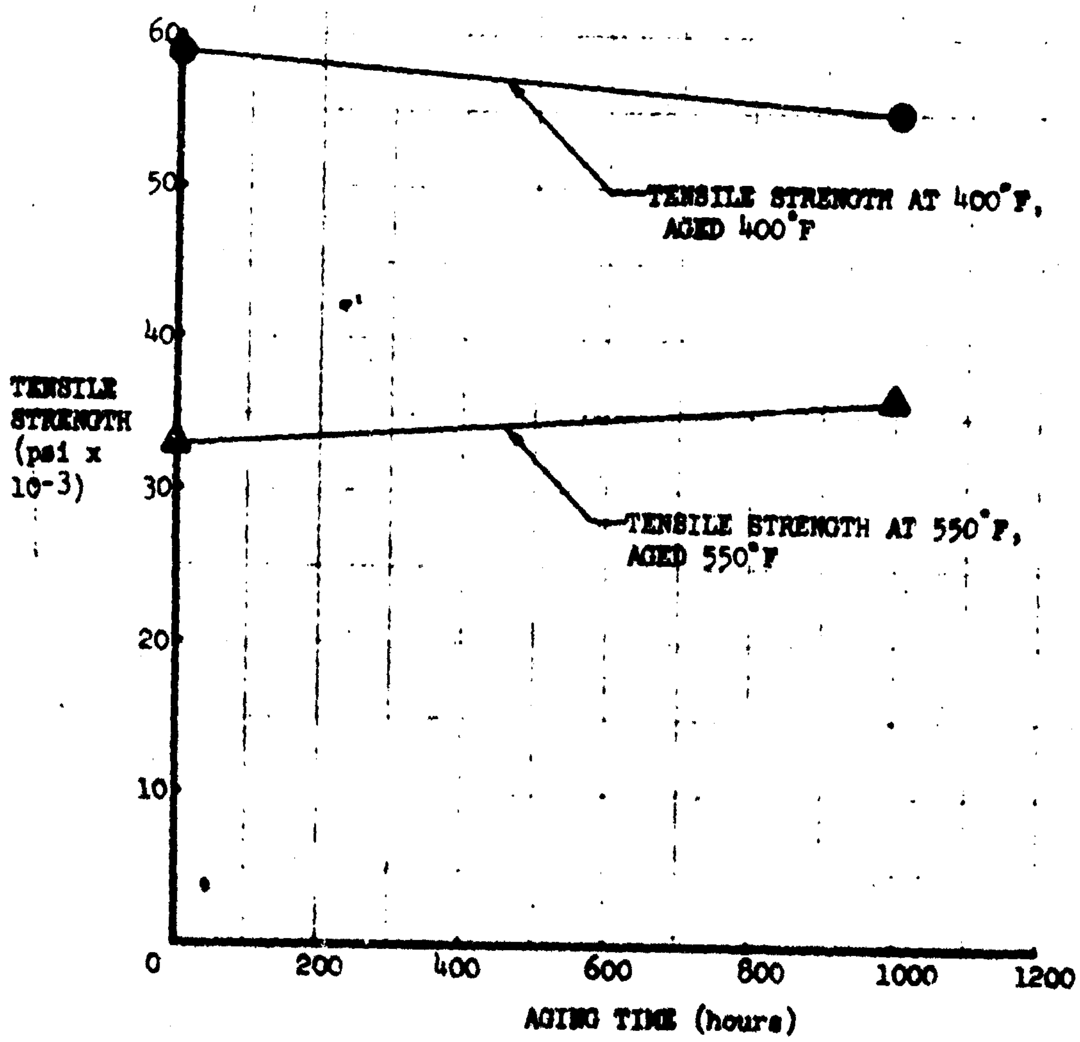


Figure 18 Tensile Strength (polyimide "E" glass, postcure to 550°F)

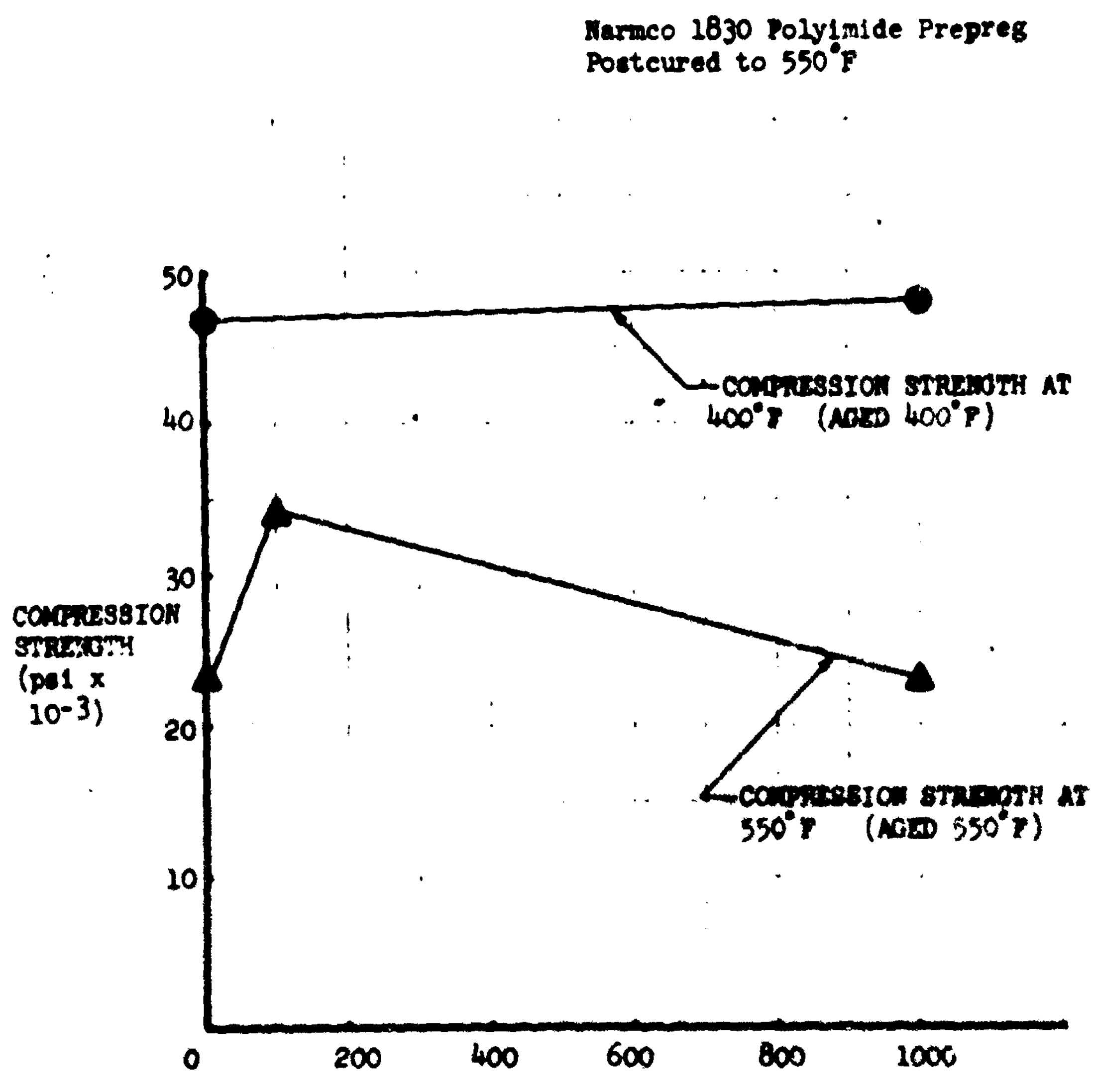


Figure 19. Compression Strength at Aging Temperature (polymide 12 plies "E" glass)

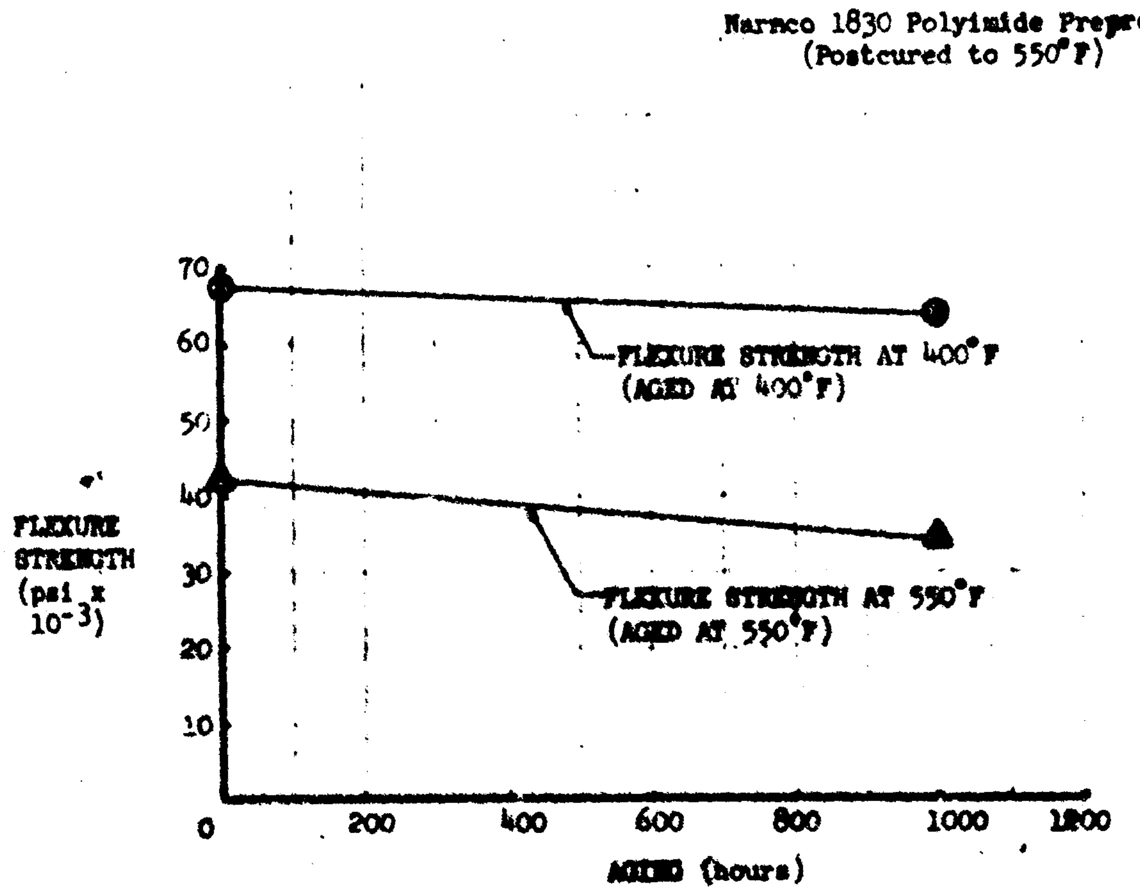


Figure 29. Flexure Strength (polyimide 12 plies "E" glass laminate)

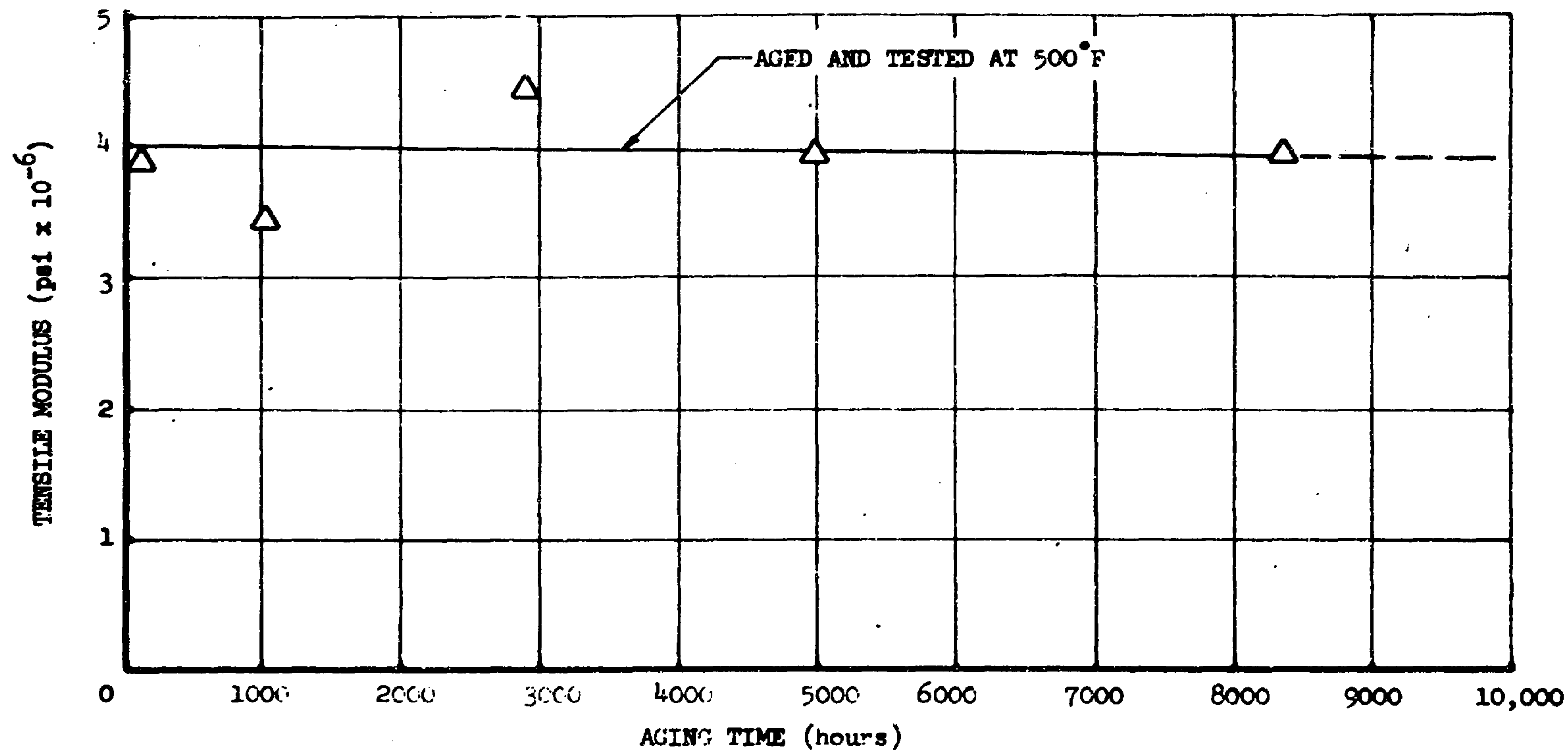


Figure 21. Tensile Modulus at Aging Temperature (polymide, 12 plies, 5 glass, 2–hr. postcure at 700°F)

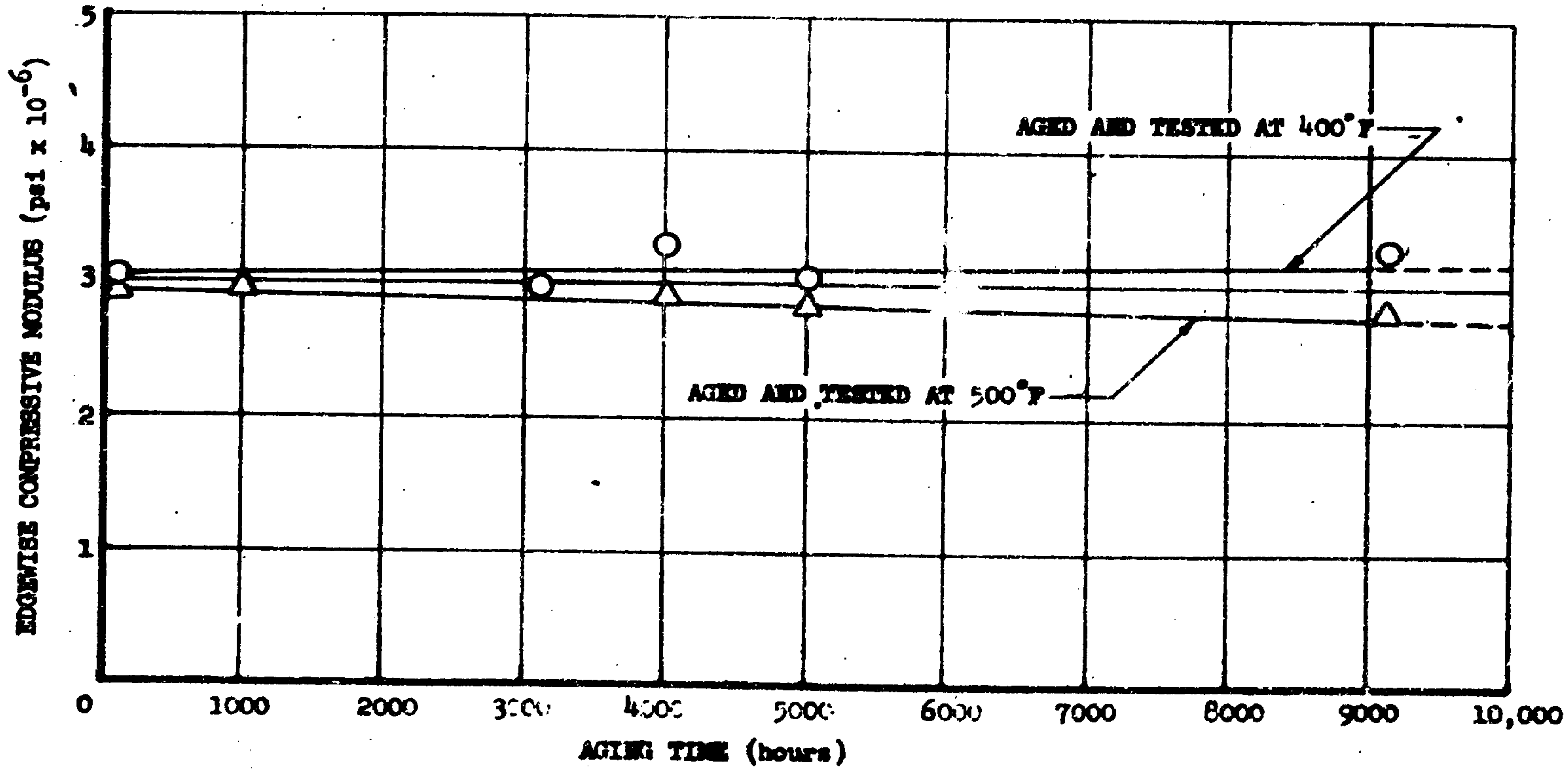


Figure 22. Edgewise Compressive Modulus at Aging Temperature (polymide, 12 plies, "E" glass, 2-hr. postcure at 700°F)

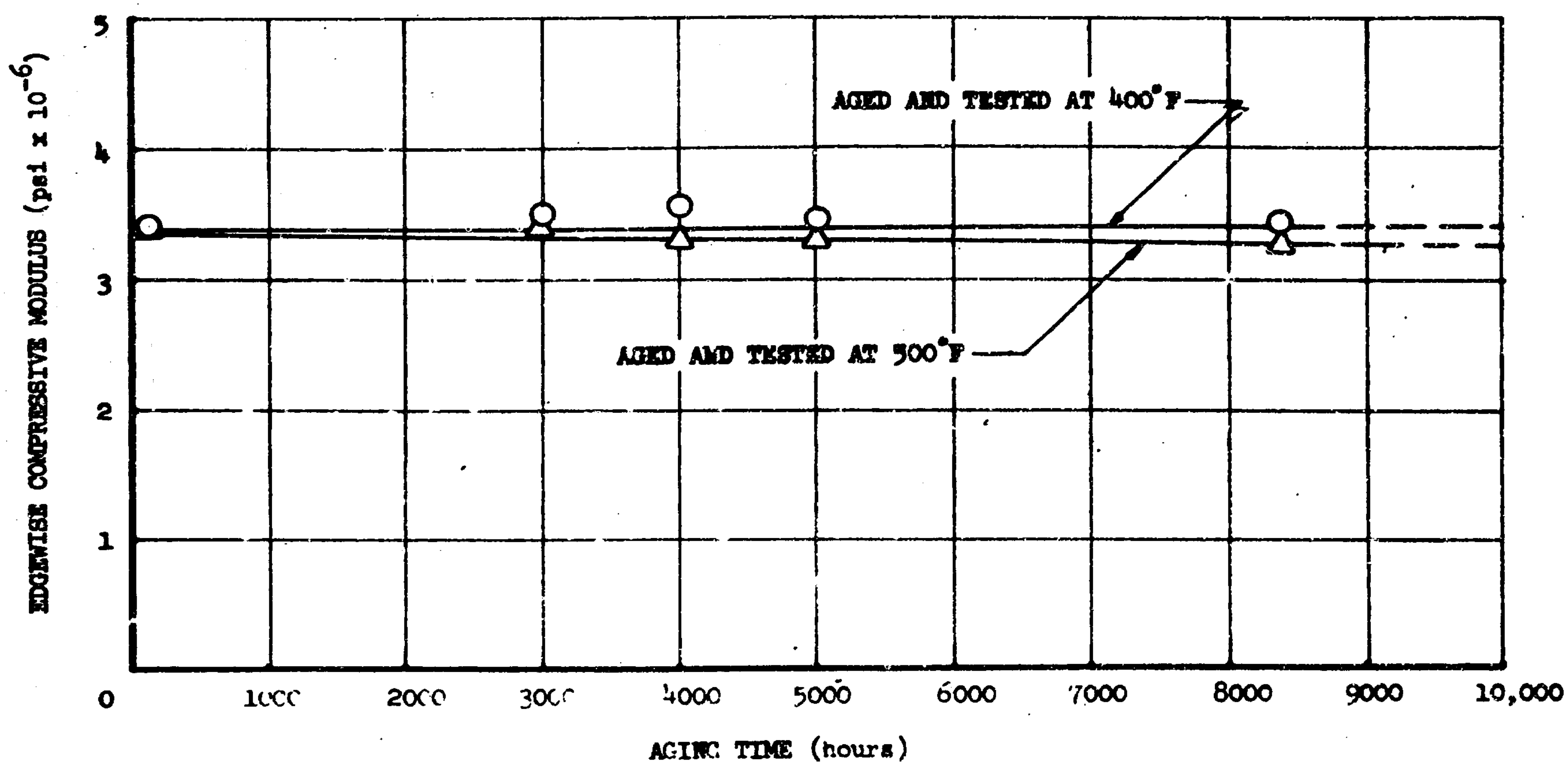


Figure 23. Edgewise Compressive Modulus at Aging Temperature (polymide, 12 plies, "S" glass, 2-hr. postcure at 700°F)

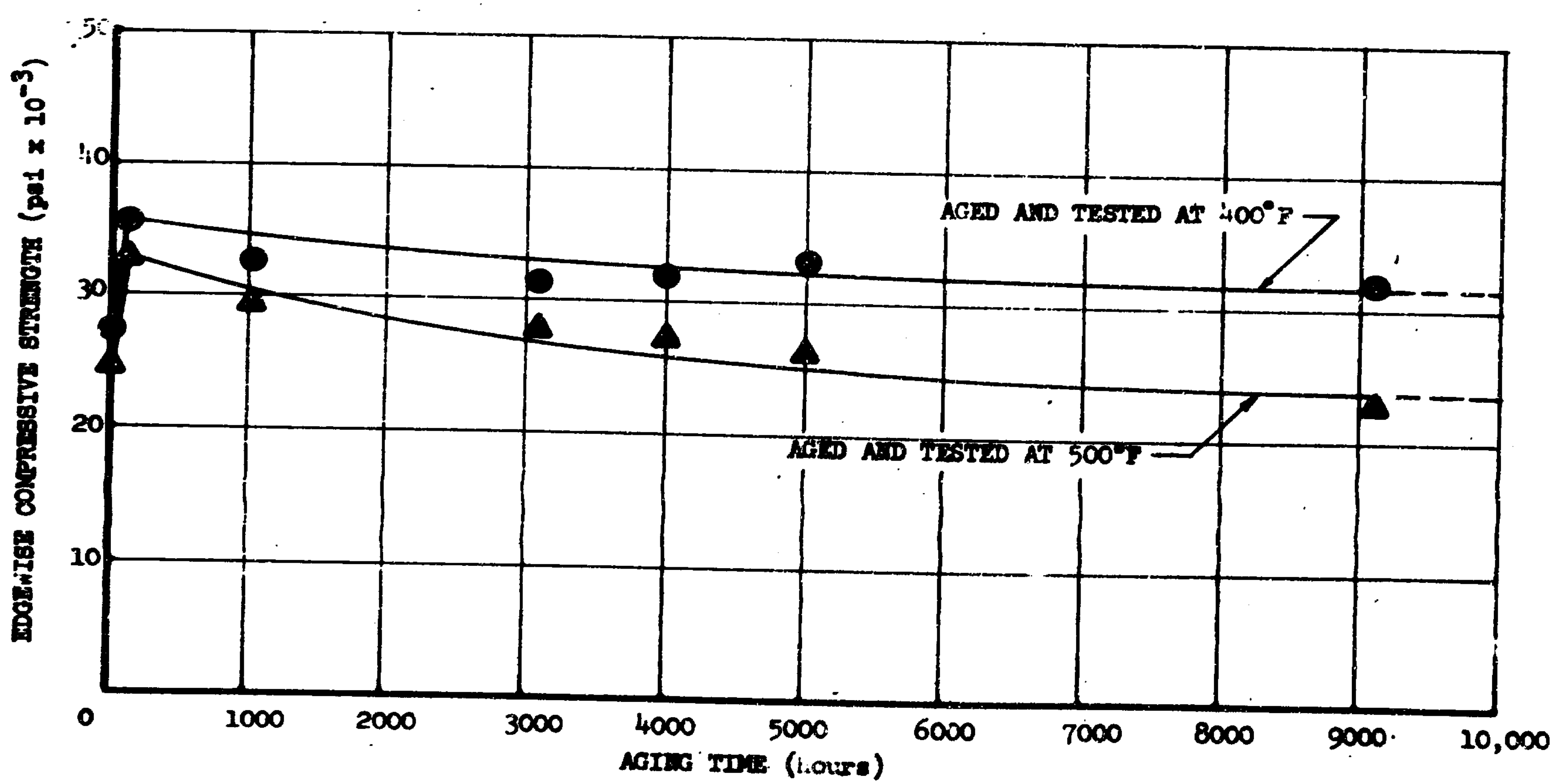


Figure 24. Edgewise Compressive Strength at Aging Temperature (polymide, 12 plies, "E" glass, 2–hr. postcure at 700°F)

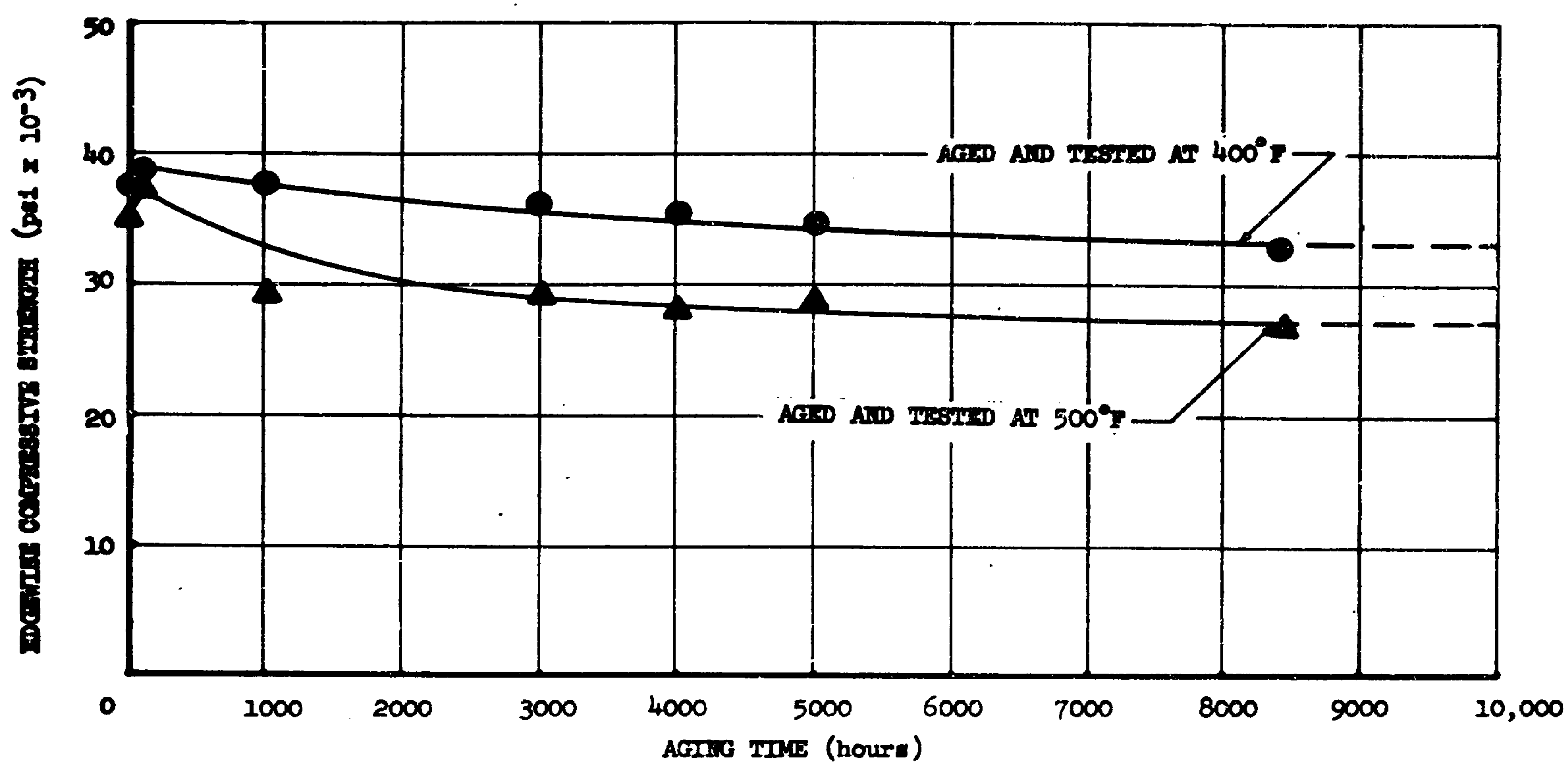


Figure 25. Edgewise Compressive Strength at Aging Temperature (polymide, 12 plies, "S" glass, 2-hr. postcure at 700°F)

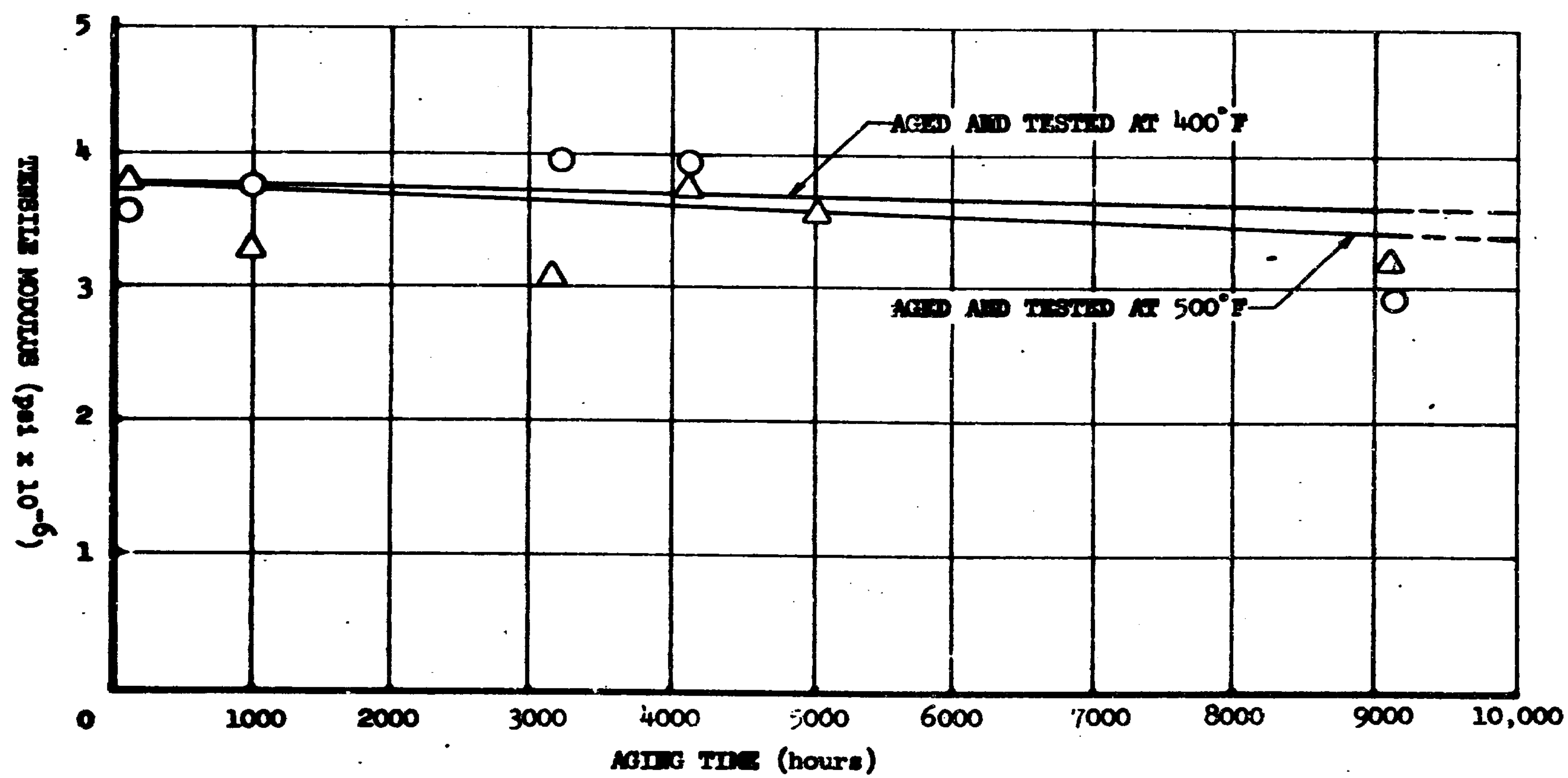


Figure 26. Tensile Modulus at Aging Temperature (polymide, 12 plies, "E" glass, 2-hr. postcure at 700°F)

1008. Materials and Processes (continued)

Specimens are being aged at 500°F and 550°F for 500 hr to determine the effect of long-term, high-temperature aging on the coefficient.

High-Temperature-Resistant, Reinforced-Plastic Honeycomb Core

Glass-fabric-reinforced polyimide honeycomb cores (HRH-324, standard weave, and HRH-327, bias weave) have been thermally aged and evaluated after 1,000 hours at 450°F. Mechanical properties of the materials at this temperature are listed in Table VII.

*Table VII. Mechanical Properties of Polyimide Core at 450 °F**

Core type	Time @ 450°F (hr)	Shear 'L' direction		Shear 'W' direction		Compression	
		Strength	Modulus	Strength	Modulus	Strength	Modulus
HRH-324	0	208	10,690	76	2,540	392	28,000
HRH-324	1/2	178	6,450	-	-	369	29,900
HRH-324	100	179	6,950	80	2,330	365	39,000
HRH-324	1,000	189	8,700	74	3,120	-	-
HRH-327	0	265	20,200	148	8,900	510	31,400
HRH-327	1/2	218	17,100	133	8,650	391	28,700
HRH-327	100	264	21,500	133	9,200	385	23,500
HRH-327	1,000	230	17,720	128	8,590	-	-

*Values corrected to 4 lb per cu ft density

The retention of mechanical properties at 450°F for these materials, as shown by the data, is quite good. HRH-327 (bias weave) continues to exhibit outstanding mechanical properties (at elevated temperatures) except for compression modulus. Thermal aging of polyimide core at 400, 500, and 500°F, last reported in the May 1966 Progress Report, is currently between 5,000 and 10,000 hours.

Wing Pivot Two-Inch Bearing Program

Materials evaluation for the wing-pivot bearings and similar applications is continuing. The effects of heat, contamination, and manufacturing process variables on bearing life are currently being investigated. Adhesives other than Epon 957 are being evaluated for general comparison and life-improvement purposes. The tests listed in Table VIII have been completed since the May 1966 Report.

A technique to measure bearing liner wear by electrical resistance has been developed and used in the 2-inch bearing test program. Results to date indicate that this inspection method is reproducible and simple; it has a potential for use on the B-2707 wing pivot bearing, either on a continuous monitoring basis or as a spot check by maintenance personnel. Tests are continuing.

Table VIII. Materials Tests – 2-Inch Wing Pivot Bearing Program.

Specimen number	Test conditions Load ksi	Test conditions Temp (°F)	Soak fluid used prior to test	Prior soak conditions (°F)	Adhesive	Bond-line thickness (mils)	Wear life Cycles [6]	Wear life Test
281	20	300	None		Epon 957	14.7	816,318	162,000
288	20	300	None		Epon 957	15.4	868,879	172,000
301 [5]	20	300	None		Epon 957		23,031	4,500
302 [5]	20	300	None		Epon 957		23,140	4,510
310	20	300	None		Epon 957	13.7	268,891	48,000
311	20	300	None		Epon 957	16.6	589,884	118,000
314	20	300	Heat only	500 hrs @ 300	Epon 957	14.9	21,688*	4,260*
293 [4]	20	300	Heat only	1000 hrs @ 300	Epon 957		893,772	176,000
327	20	300	Heat only	1000 hrs @ 300	Epon 957	15.1	164,984	32,000
300 [3]	20	300	Heat only	1000 hrs @ 300	Epon 957	14.7	322,851	57,400
330	20	400	Heat only	1000 hrs @ 400	Epon 957	14.3	93,641	18,100
331	20	400	Heat only	1000 hrs @ 400	Epon 957	14.8	255,912	49,500
334	10	450	Heat only	1000 hrs @ 450	Epon 957	14.4	117,361	22,600
297	20	300	MIL-A-8243 Anti-icer	[1]	Epon 957	14.5	543,906	106,200
295	20	300	MIL-C-15074 Fingerprint Remover	[1]	Epon 957	14.0	188,929	33,400
264	20	300	CEEBEE 280	[1]	Epon 957	13.9	871,130	166,5[illegible]0
296	20	300	CEEBEE 280	[2]	Epon 957	14.5	10,807	2,1[illegible]0
313	20	300	Heat only	500 hrs @ 300	FXM-34B-34	13.1	65,188	12,8[illegible]0
312	20	300	Heat only	500 hrs @ 300	FXM-34B-34	13.2	67,187	11,900
318	20	400	Heat only	500 hrs @ 400	FXM-34B-34	13.1	136,939	26,800

[1] Soaked for 22 hr @ room temperature, then dried for 2 hours @ 300°F. Cycle repeated 10 times

[2] Immersed in fluid for 10 days @ 200°F

[3] Manufactured by Southwest Products Co.

[4] Manufactured by Transport Dynamics, Inc.

[5] Manufactured by Rex C. Hainbelt Co.

[6] Failure occurs when shaft wears through fabric-adhesive liner to metal ring.

* Test shaft was cocked. Test invalid.

1008. Materials and Processes (continued)

Figure 27 summarizes the results of the fluid compatibility tests performed to date on the 2-in.-diameter bearings.

Surface Treatment of Titanium for Adhesive Bonding

Sufficient tests have been completed on parameters of the Pasa Jell 107 process to establish it as the optimum prebond surface treatment, and preparation of detailed process specification coverage has commenced. The most recent tests determined that (1) the precautions necessary for preventing deterioration of surfaces after Pasa Jell 107 application, (2) the Pasa Jell 107 solution may be reactivated after usage with additions of hydrofluoric acid, without affecting bond strength, and (3) abrasive blasting with alumina prior to Pasa Jell 107 application, when permitted by parts' configurations, gives good bond strength.

Surface change after Pasa Jell 107 application was particularly investigated, since surface potential measurements previously showed that titanium hydrates readily on contacting air or hot water (e.g., from rinsing). The recent lap bond shear tests did reveal a strength loss of 800 psi following the standard water-boil exposure when hot water had contacted the treated surfaces. Air contact of 24 hours did not cause a loss of bond strength under the testing conditions.

The Pasa Jell 107 process, with normal precautions of rinsing and protection after treatment, yields initial bond strengths of 3200 to 3600 psi; strengths after the standard, 3-day water-boil test of 2250 to 2400 psi; and strengths after the standard 14-day, 600°F, heat-aging test of 1900 to 2150 psi.

Heat and Fuel Resistant Foams

Two Boeing formulated and developed polyurethane foams previously tested and reported(1) have been exposed to extended fuel-soak/thermal-aging cycling tests. Each test cycle consisted of 72 hours exposure to JP-5 fuel at 250°F, followed by another 72 hours thermal aging at 400°F. Weight loss and dimensional change were determined at the end of a cycle at selected intervals. Results are graphically presented in Fig. 28. Although there were changes in weight and dimensions during the first 1,000 hours of exposure, insignificant changes were observed between 1,000 to 2,500 hours for foam 947, and between 1,000 to 1,600 hours for the foam 949. Also, the 20 percent total weight loss after the 2500-hr and 1600-hour exposures represents a marked improvement in thermal and dimensional stability over similar commercial foams tested; the latter showed severe distortion after 100 hr and a 30-percent weight loss after 500 hours.

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(1) reported in March and May Bimonthly Technical Progress Reports.

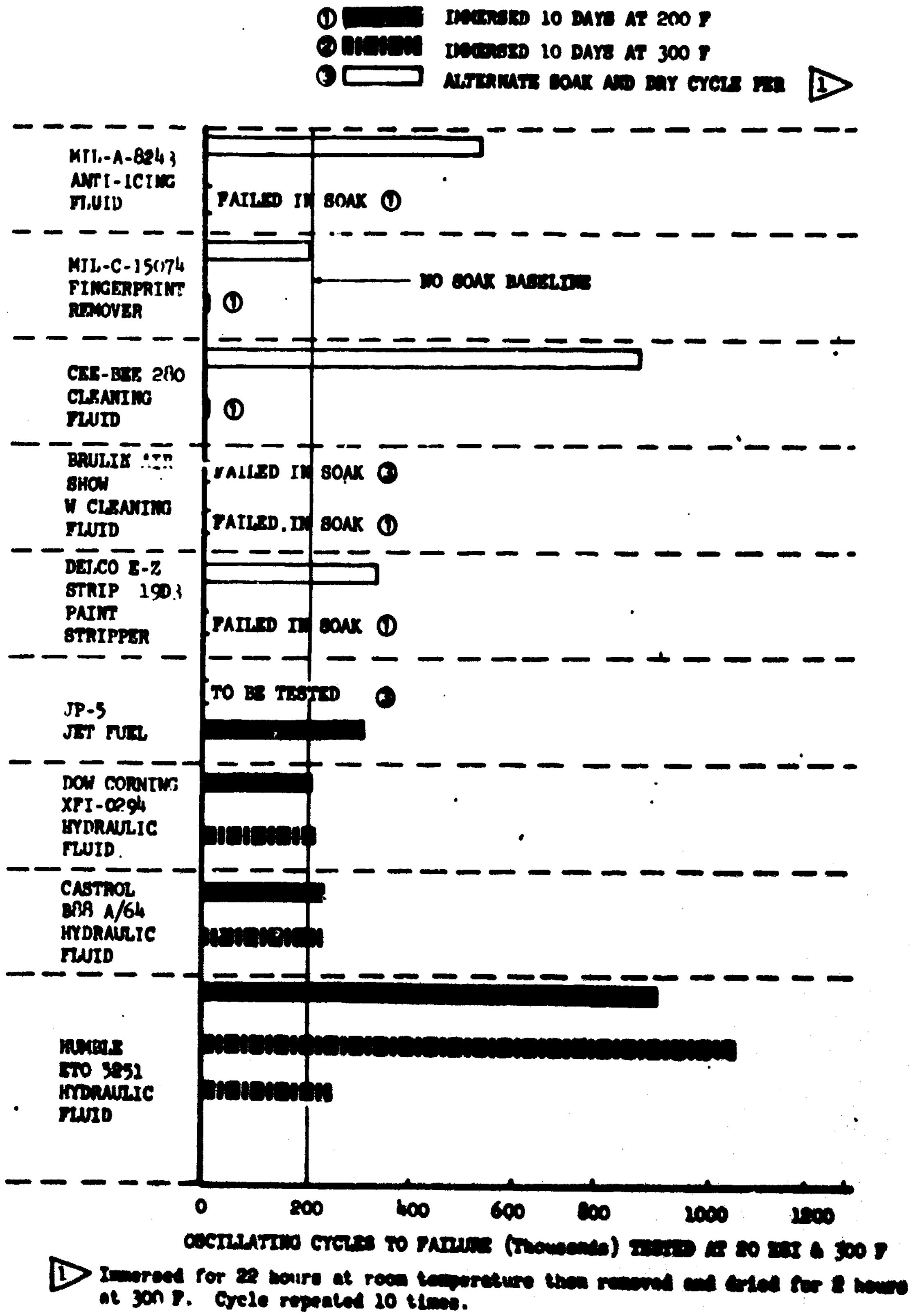


Figure 22. Fluid Compatibility Tests–Bearing Program, 2-in. Dia Epon 957/Teflon–F/G Cloth

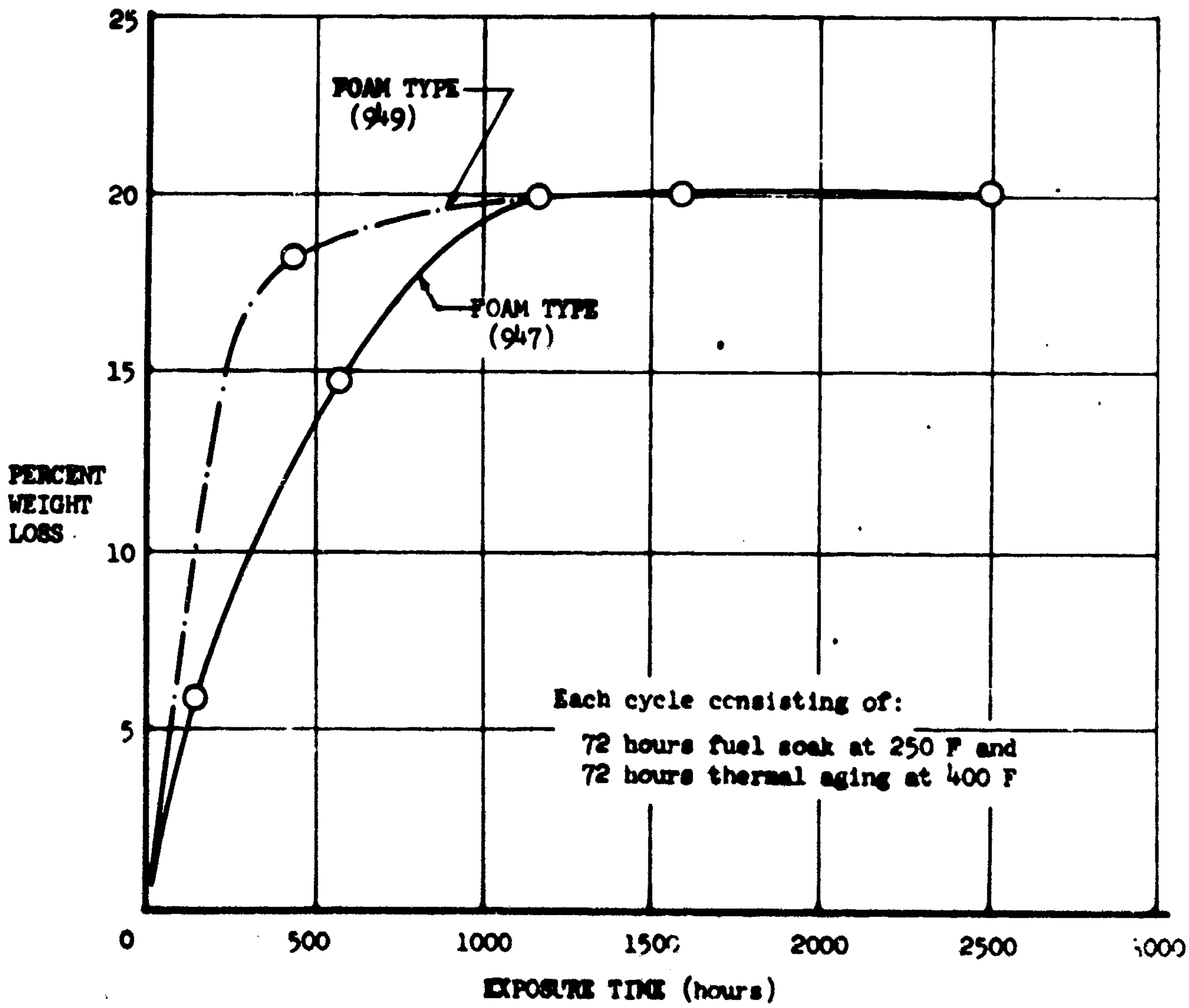


Figure [illegible]. Fuel Soak Thermal-Aging Cycling

III. Description of Technical Progress (continued)

1008. Materials and Processes (continued)

Presently, foam types 947 and 949 are undergoing extensive heat aging from 350 to 400°F, and additional testing to determine the mechanical properties after aging. It is anticipated that these foams will be suitable for structural insulation applications where the foamed parts may be exposed to jet fuel or high temperatures (300 to 400°F) continuously.

Adhesives

Weight-reduction efforts included bonding tests of differing weights of the polyimide adhesive with the following results:

Honeycomb Peel:					
Adhesive weight, uncured	(psf)	0.138	0.122	0.086	0.069
Cured bond-line weight including core roller-coat and/or primer	(psf)	0.131	0.126	0.094	0.083
Initial RT peel torque (corrected for skin stiffness) (in.-lbs/3 in. width)		50	52	32.5	24
Peel torque/weight	(ft^2)	380	410	346	289
Lap-bond Shear:					
*Bond-line thickness	(in.)	0.0078	0.0079	0.0076	0.0068
Initial RT shear strength	(psi)	3160	3500	3200	3430
After 3-day water boil	(psi)	2570	2360	2570	2310
After 2 weeks at 600°F	(psi)	2060	2320	1870	2150

NOTES:

***Lap-bond assemblies are shimmed for 5-mil minimum bond-line thickness, so it appears actual bond lines are not limited by the shims, yet did not vary significantly with adhesive film weight.**

Conclusion:

Reducing FXM-34B-25A (XBMS 5-53) adhesive film weight by as much as 50 percent appears to sacrifice little of the shear strength properties.

Forming

The room temperature formability of Ti 6Al-4V was improved significantly by the use of urethane pad brake forming dies. The minimum bend radius obtained when using Grade L-167 (Durometer 95A hardness) urethane and conventional channel dies is shown in Fig. 29.

Ti 6Al-4V Thick Section Study

A study to determine the variation of Ti 6Al-4V mechanical properties with section thickness is complete. Static tensile, plane-strain fracture toughness, saltwater stress-corrosion resistance, and fatigue properties of Ti 6Al-4V in the Beta-STA-1250 heat-treatment condition were determined for material thicknesses from 0.125 to 6.0 in. Two heats of material were tested: the alloy chemistry of one heat (heat A) was near the upper specification limits while the composition of the other heat (heat B) was at the low end of the specification range, thus representing the extremes in chemical composition.

Figure 30 shows the variation of strength, toughness, and stress-corrosion resistance with section thickness. Both surface and core properties were determined for the heavier sections, although only core properties for strength and surface properties for toughness and stress-corrosion resistance are shown (since they represent the most conservative values).

Figure 31 is an S-N curve showing a summary of the fatigue data for Beta-STA-1250 Ti 6Al-4V. All test results lie close to this curve, regardless of the heat or material thickness.

Investigation of Titanium Alloy Extrusions

Two Ti 6Al-4V production extrusions (Fig. 32), worked in the beta range were evaluated for mechanical properties and metallurgical soundness to determine their applicability for B-2707 structure. Static tensile and compression strengths were determined at -65°, 70°, and 500°F for annealed, solution-treated, and aged samples at 1000°F (STA-1000), and for solution-treated and aged samples at 1250°F (STA-1250) conditions in both longitudinal and transverse grain direction. Notched (K_t = 2.58) tension-tension fatigue properties were determined at ambient temperature for the annealed (STA-1000 and STA-1250 conditions), and slow-notch-bend properties were used to establish base line (K_{Ic}) and environmental (K_{Ii}) fracture toughness for all three thermal conditions. The environmental fracture, toughness properties were tested in a 3.5 percent salt solution.

The test data indicates material properties of typical extrusions are comparable to that for other forms of beta-treated Ti 6Al-4V. Static tension and compression properties (Tables IX through XIV) fall within a normal bend for Ti 6Al-4V at all test temperatures and heat treatments. No significant difference in tensile

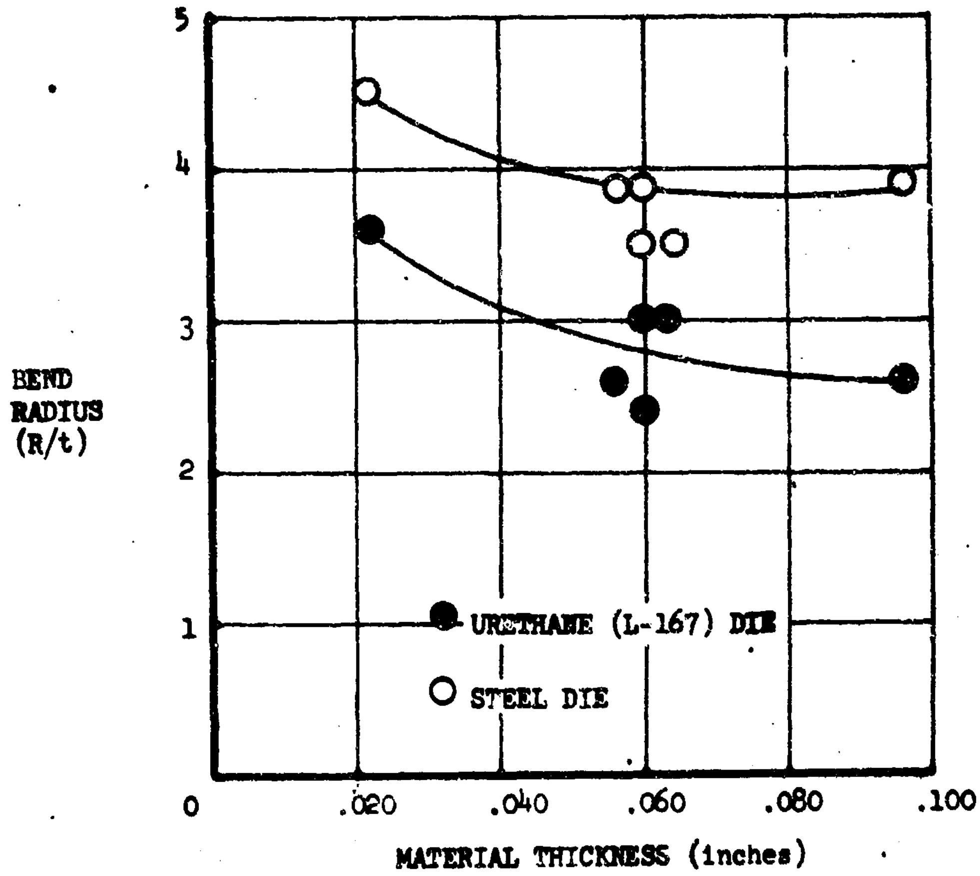


Figure 29. Room-Temperature Bend Radius for Annealed Ti 6Al-4V Radii

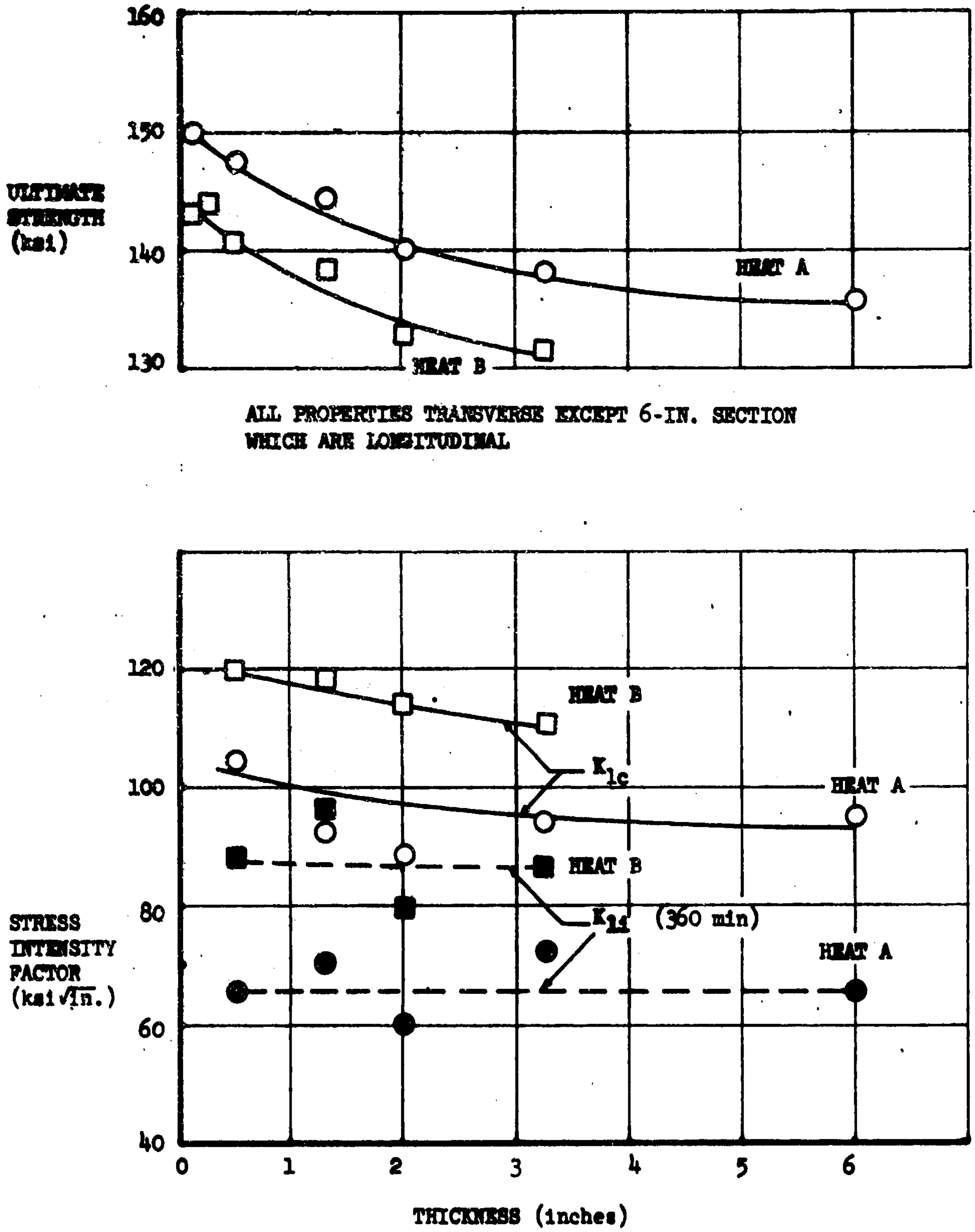


Figure 30. Effect of Section Size on Strength, Toughness, and Stress-Corrosion Resistance of Ti 6Al-4V, Beta-STA-1250

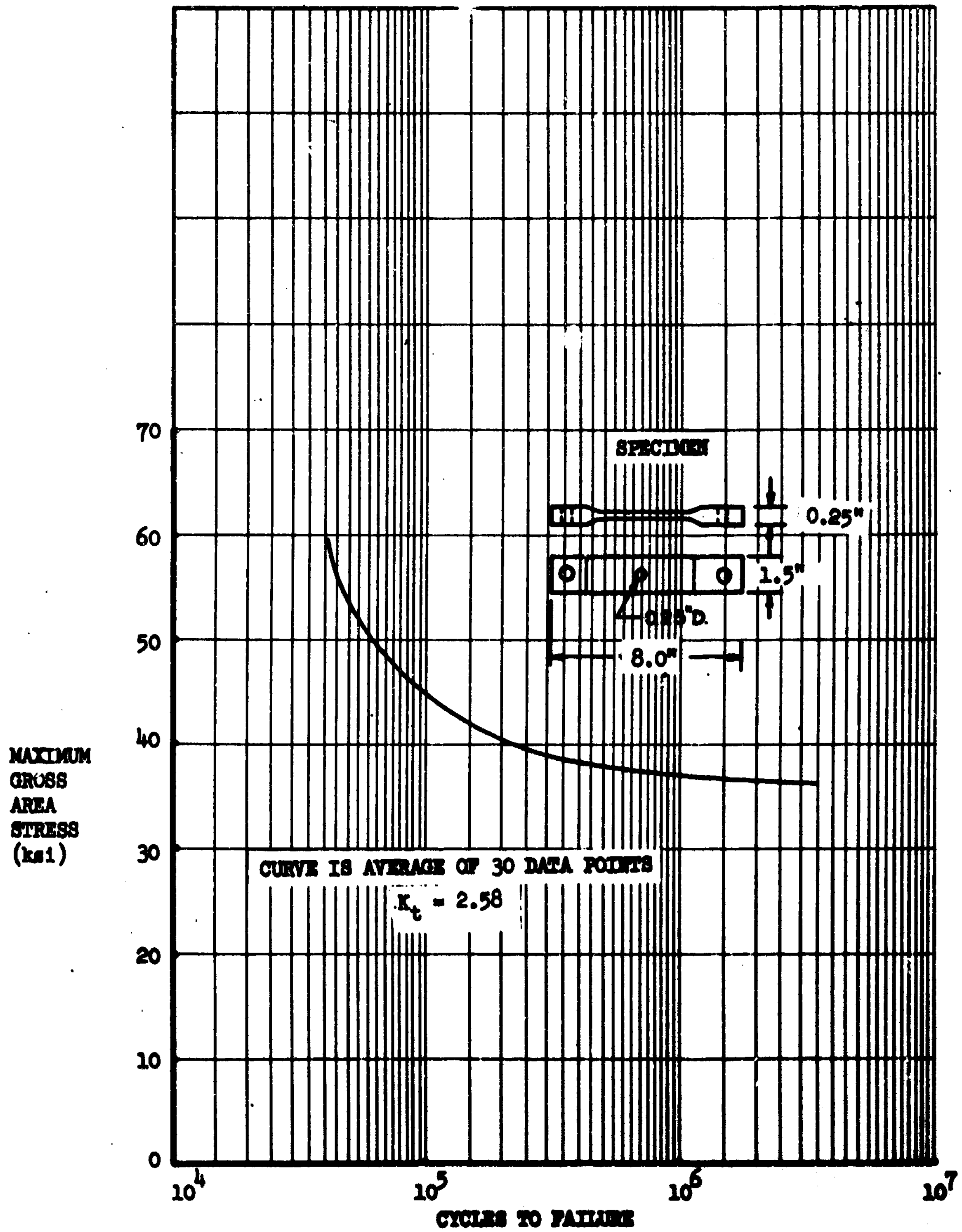


Figure 31. Fatigue Characteristics of Ti 6Al-4V, BETA-STA-1250

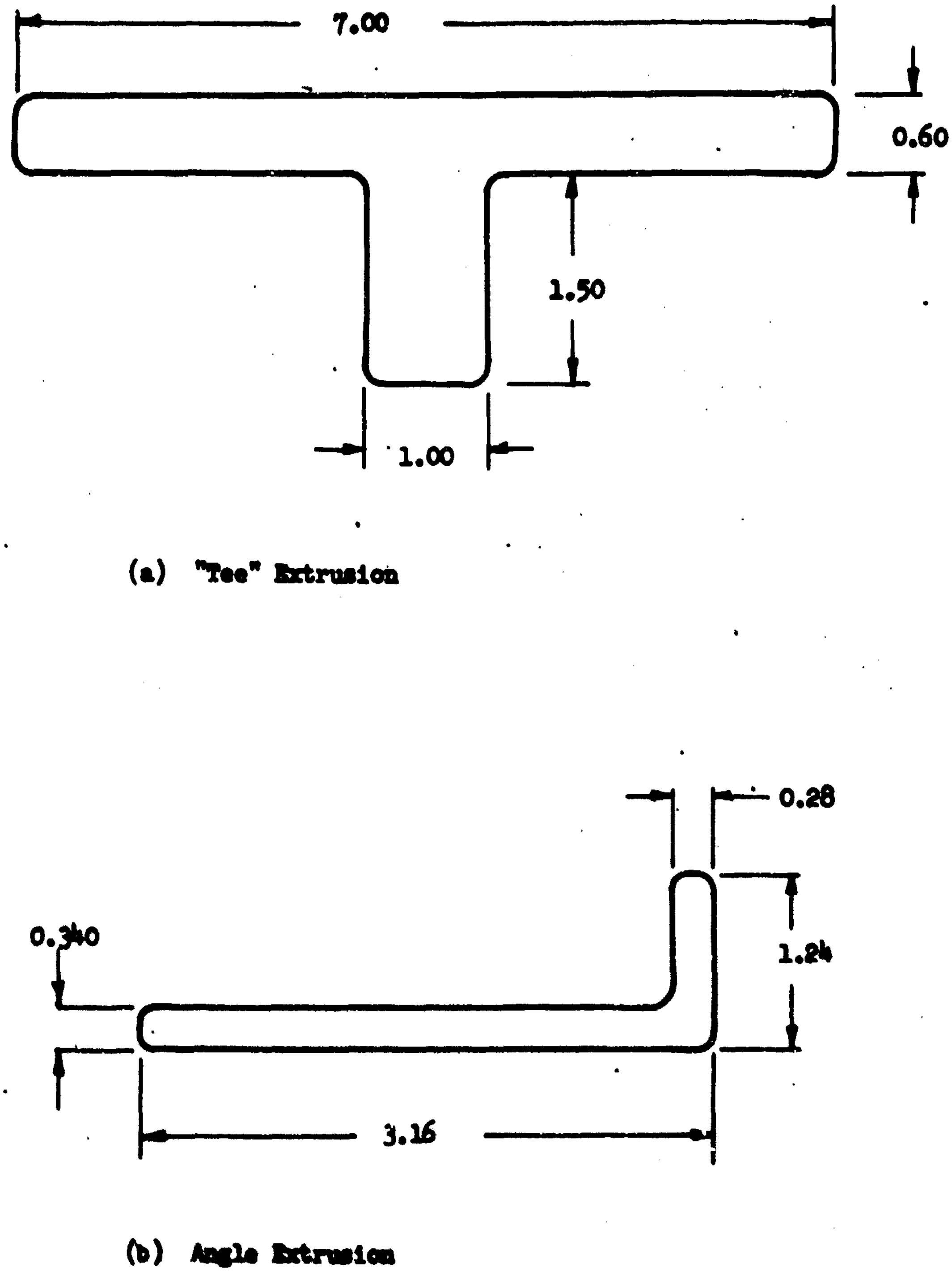


Figure 32. Titanium 6Al-4V Extrusion Shapes

Table IX. Tensile Properties of Titanium 6Al-4V "Tee" Extrusion - (Annealed at 1300°F for 2 Hours, Air-Cooled)

Spec No.	Test Temp (°F)	Grain Direction	Tensile Stress (ksi)	0.2% Offset Yield Stress (ksi)	Elongation (% in 1 inch)	Reduction of Area (%)
1	75	Long.	143.8	126.1	14	36
2	75	Long.	142.1	126.8	14	32
3	75	Long.	142.8	126.3	14	33
4	75	Long.	140.4	124.1	14	29
Average			142.3	124.3	14.0	32.5
5	75	Trans	144.7	129.7	14	31
6	75	Trans	143.8	127.6	14	37
7	75	Trans	143.2	125.9	13	32
8	75	Trans	142.6	125.1	12	32
Average			143.6	127.1	13.2	33.0
9	-65	Long.	158.9	- *	11	27
10	-65	Long.	160.2	142.8	11	28
11	-65	Long.	163.0	148.6	12	31
12	-65	Long.	**	-----	--	--
Average			160.7	145.7	11.3	28.7
13	-65	Trans	157.5	142.8	11	30
14	-65	Trans	157.2	141.9	10	26
15	-65	Trans	158.8	141.4	11	28
16	-65	Trans	162.1	146.5	11	29
Average			158.9	143.1	10.7	28.2
17	500	Long.	102.4	77.3	18	51
18	500	Long.	97.7	72.0	19	52
19	500	Long.	102.7	76.7	18	51
20	500	Long.	101.8	77.8	19	49
Average			101.1	75.9	18.5	50.7
21	500	Trans	105.5	80.9	16	42
22	500	Trans	103.7	81.0	16	46
23	500	Trans	103.3	78.8	17	47
24	500	Trans	104.1	80.0	16	48
Average			104.1	80.2	16.2	45.7

* Yield point could not be taken from curve

** Threads stripped

Table X. Tensile Properties of Titanium 6Al–4V "Tee" Extrusion (Solution–Treated 1725°F for 30 Min, Water–Quenched; Aged at 1000°F for 4 Hours, Air–Cooled)

Spec No	Test Temp (°F)	Grain Direction	Tensile Stress (ksi)	0.2% Offset Yield Stress (ksi)	Elongation (% in 1 inch)	Reduction of Area (%)
25	75	Long.	166.1	149.2	11	30
26	75	Long.	161.8	145.4	10	25
27	75	Long.	163.3	144.9	10	21
28	75	Long.	163.0	148.2	10	22
Average			163.5	146.9	10.2	26.2
29	75	Trans	171.2	154.0	8	19
30	75	Trans	168.0	152.1	9	21
31	75	Trans	165.2	148.3	11	25
32	75	Trans	168.3	151.7	10	24
Average			168.2	149.0	9.5	22.2
33	-65	Long.	180.5	167.6	8	18
34	-65	Long.	184.2	169.1	8	18
35	-65	Long.	182.0	165.8	9	17
36	-65	Long.	184.5	168.6	7	24
Average			182.8	167.8	8.2	19.2
37	-65	Trans	186.3	169.9	7	16
38	-65	Trans	185.7	168.8	9	21
39	-65	Trans	188.0	171.4	5	15
40	-65	Trans	185.4	169.7	7	18
Average			186.3	169.9	7.0	17.5
41	500	Long.	127.2	97.3	17	49
42	500	Long.	124.0	94.0	17	48
43	500	Long.	126.2	95.5	15	44
44	500	Long.	128.8	96.8	14	32
Average			126.5	95.9	15.7	43.2
45	500	Trans	127.2	98.7	14	43
46	500	Trans	130.5	101.0	11	34
47	500	Trans	129.3	101.0	12	31
48	500	Trans	129.7	100.8	13	34
Average			129.2	100.4	12.5	35.5

Table XI. Tensile Properties of Titanium 6Al-4V "Tee" Extrusion (Solution-Treated - 1725°F for 30 Min, Water-Quenched; Aged at 1250°F for 4 Hours, Air-Cooled)

Spec No.	Test Temp (°F)	Grain Direction	Tensile Stress (ksi)	0.2% Offset Yield Stress (ksi)	Elongation (% in 1 inch)	Reduction of Area (%)
49	75	Long.	153.6	134.7	14	35
50	75	Long.	154.7	140.5	12	30
51	75	Long.	154.3	140.7	11	29
52	75	Long.	154.9	141.9	11	21
Average			154.4	139.4	12.0	28.7
53	75	Trans	154.7	139.9	12	32
54	75	Trans	154.7	140.7	10	30
55	75	Trans	154.9	139.8	11	26
56	75	Trans	155.6	140.9	10	22
Average			155.0	140.3	10.7	27.5
57	-65	Long.	171.8	160.0	9	21
58	-65	Long.	173.3	162.2	8	23
59	-65	Long.	171.9	159.9	8	18
60	-65	Long.	173.7	161.3	11	28
Average			172.7	160.8	9.0	22.5
61	-65	Trans	175.2	160.1	9	20
62	-65	Trans	177.4	163.5	8	23
63	-65	Trans	175.5	161.4	7	17
64	-65	Trans	174.3	160.7	8	19
Average			175.5	161.4	8.0	19.7
65	500	Long.	114.4	88.8	20	57
66	500	Long.	112.9	89.0	18	49
67	500	Long.	117.7	91.9	17	49
68	500	Long.	115.2	90.4	19	50
Average			115.0	90.0	18.5	51.2
69	500	Trans	118.2	93.2	15	41
70	500	Trans	118.4	92.6	17	50
71	500	Trans	117.3	92.8	17	47
72	500	Trans	117.5	91.9	17	46
Average			117.8	92.6	16.5	46.0

Table XII. Tensile Properties of Titanium 6Al-4V "Tee" Extrusion Heavy Section for Three Heat Treatments

Spec No.	Test Temp (°F)	Grain Direction	Tensile Stress (ksi)	0.2% Offset Yield Stress (ksi)	Elongation (% in 1 inch)	Reduction of Area (%)
Annealed at 1300°F for 2 hours, air-cooled						
1	75	Long.	139.5	121.6	14	33
2	75	Long.	139.9	122.0	15	33
3	75	Long.	138.1	120.2	13	33
4	75	Long.	138.9	121.0	15	35
Average			139.1	121.2	14.2	33.5
Solution-treated at 1725°F for 30 min, water-quenched, aged at 1000°F for 4 hours, air-cooled						
5	75	Long.	150.6	133.6	12	28
6	75	Long.	153.4	136.3	11	24
7	75	Long.	155.5	138.6	11	27
8	75	Long.	153.5	137.1	11	28
Average			153.2	136.1	11.2	26.7
Solution-treated at 1725°F for 30 min, water-quenched, aged at 1250°F for 4 hours, air-cooled						
9	75	Long.	145.7	131.6	13	31
10	75	Long.	146.0	131.0	14	31
11	75	Long.	146.5	132.4	12	28
12	75	Long.	148.6	133.6	12	27
Average			146.7	132.1	12.7	29.7

Table XIII. Room Temperature Tensile Properties of Titanium 6Al–4V Angle Extrusion

Spec No.	Test Temp (°F)	Grain Directions	Tensile Stress (ksi)	0.2% Offset Yield Stress (ksi)	Elongation (% in 1 inch)	Reduction of Area (%)
Annealed at 1300°F for 2 hours, air-cooled						
1	75	Long.	141.1	128.2	15	33
2	75	Long.	141.6	129.0	14	31
3	75	Long.	141.4	129.0	14	31
4	75	Long	143.0	129.4	15	29
Average			141.8	128.9	14.5	31.2
Solution-treated at 1725°F for 30 min, water-quenched, aged at 1000°F for 4 hours, air-cooled						
5	75	Long.	158.1	145.3	11	24
6	75	Long.	162.0	147.6	10	19
7	75	Long.	159.9	146.2	10	23
8	75	Long.	159.9	143.8	10	23
Average			160.0	145.7	10.2	22.2
Solution-treated at 1725°F for 30 min, water-quenched, aged at 1250°F for 4 hours, air-cooled						
9	75	Long.	150.6	140.4	12	29
10	75	Long.	151.6	141.4	13	29
11	75	Long.	149.9	138.3	12	28
12	75	Long.	152.3	141.0	12	28
Average			151.1	140.3	12.2	28.5

Table XIV. Compressive Yield Strength of Titanium 6Al–4V Extrusions

Heat Treatment	Test Temp (°F)	0.2% Offset Compression Yield Strength TEE Long.	Trans	Heavy Section (Long.)	Angle Long.
Annealed at 1300°F for 2 hours, air-cooled	75	137.4 137.2 136.7 139.1	138.2 137.8 140.3 138.0	136.3 135.0 135.2 137.0	143.1 132.3 143.2 142.1
Average		137.6	138.5	135.7	140.2
Solution-treated at 1725°F for 30 min, water-quenched, aged at 1000°F for 4 hrs, air-cooled	75	161.5 159.6 157.2 158.2 159.8	166.7 163.2 161.3 166.7 163.0	147.8 152.8 152.5 153.5 153.5	156.9 156.3 158.6 170.2 160.7
Average		159.3	164.2	151.6	160.6
Solution-treated at 1725°F for 30 min, water-quenched, aged at 1250°F for 4 hrs, air-cooled	75	150.7 148.6 148.2 147.2 148.3	148.9 150.7 151.0 151.8 150.4	146.4 146.2 146.0 ----- -----	151.7 154.8 148.4 148.4 145.4
Average		148.6	150.3	146.2	151.2

properties for longitudinal or transverse grain direction is apparent; however, thick-section (1 in.) properties are somewhat lower than those for the thinner sections. Compression yield strength is comparable to, or slightly lower than, the ultimate tensile strength.

Notched fatigue results show no significant difference for extrusion shape or thermal treatment (Tables XV and XVI). Slow-notch-bend test results are given in Tables XVII through XX, and the toughness properties are summarized below. The toughness appears comparable for the two extrusion shapes and thermal conditions and is in agreement with tests conducted on beta-treated Ti 6Al-4V plate.

Heat Treatment	Intensity Factors	Ti 6Al-4V 'Tee' Extrusion	Ti 6Al-4V Angle Extrusion
Solution-Treated	K_{Ic}	65.8	67.3
and Aged at 1000°F	K_{Ii}	46	51
Solution-Treated	K_{Ic}	77.8	71.5
and Aged at 1250°F	K_{Ii}	60	70
Mill	K_{Ic}	89.6	83
Annealed	K_{Ii}	65	73

The transformed beta (basket weave) microstructure, characteristic of Ti 6Al-4V worked above the beta transus, does not have an embrittling effect on extrusions. Static, fatigue, and toughness properties for extrusions are similar to those for other material forms.

Mechanical Joint Fatigue Life Study

The effect of heading force on joint-fatigue properties was investigated. Ti 6Al-4V specimens were joined with A286 rivets headed with a 3/16-in. universal (An470 configuration) head die. Figure 29 shows a significant increase in fatigue life as the heading force is increased to 32,000 lb. Above this force, a relatively small gain in fatigue life occurs at the lower stress levels.

The effect of time-temperature-stress exposure on the fatigue properties of these joints is shown in Fig. 34. The data shows some loss in fatigue strength after exposure. Figure 35 compares fatigue properties of manually drilled holes with those for precision drilled holes. Preliminary data indicates no significant variation due to hole preparation.

Table XV. Notch Fatigue Properties of Ti-6Al-4V Tee Extrusions (K_t = 2.58)

Stress Level (KSI)	Annealed at 1300°F for 2 hrs, AC (cycles to Failure)	Sol.-treated at 1725°F for 30 min, W. Q., aged at 1000°F 4 hrs, (cycles to Failure	Sol.-treated at 1725°F for 30 min, W. Q., aged at 1250°F for 4 hrs, AC (cycles to Failure)
60	23,000	23,000	31,000
60	27,000	28,000	21,000
60	22,000	19,000	19,000
60	27,000		
Average	25,000	23,300	23,700
40	138,000	79,000	53,000
40	226,000	423,000*	105,000
40	77,000	64,000	80,000
40	141,000	483,000*	126,000
Average	145,000	262,000	91,000
35	111,000	218,000	119,000
35	118,000	242,000	83,000
35	92,000	6,726,000 (NF)	115,000
35	1,256,000*	847,000	111,000
		2,105,000 (NF)	
34	280,000	108,000	177,000
34	2,021,000 (NF)	2,402,000 (NF)	1,515,000*
32	2,487,000 (NF)	1,918,000*	2,488,000 (NF)
32	2,000,000 (NF)	2,429,000 (NF)	2,257,000 (NF)

* Grip failure

NF = No failure

Table XVI. Notched Fatigue Properties of Ti-6Al-4V Angle Extrusion (K_t=2.58)

Stress Level (KSI)	Annealed at 1300°F for 2 hrs, AC (cycles to Failure)	Sol.-treated at 1725°F for 30 min, W. Q., aged 100°F 4 hrs, AC (cycles to Failure)	Sol.-treated at 1725°F for 30 min, W. Q., aged at 1250°F for 4 hrs, AC (cycles to Failure)
60	21,000	17,000	21,000
60	18,000	22,000	20,000
60	17,000	32,000	20,000
Average	18,200	24,000	20,300
40	249,000	148,000	164,000
40	101,000	99,000	90,000
40	83,000	88,000	807,000*
Average	144,000	111,000	354,000
35	136,000		2,078,000 (NF)
35	216,000	253,000	2,103,000 (NF)
35	2,319,000 (NF)	112,000	350,000
35	231,000	2,300,000 (NF)	422,000*
35		148,000	2,703,000 (NF)
35		2,360,000 (NF)	
34	1,893,000	2,284,000 (NF)	2,170,000*
34	1,713,000*	2,465,000 (NF)	2,500,000 (NF)
34	2,983,000*		
30	2,031,000 (NF)		

* Grip failure

NF = No failure

Table XVII Fracture Toughness of Titanium 6Al–4V "Tee" Extrusion (Annealed at 1300°F for 2 Hours, Air-Cooled)

Spec No.	Grain Direction	Environment	Crack Length (a)	Load (lb)	K_I	Time to failure (min)
1	L	Air	0.26	24.2	88.4	
2	L	Air	0.39	18.8	86.9	
3	L	Air	0.44	18.65	93.5	
Average					89.6	
4	T	Air	0.45	18.75	95.8	
5	T	Air	0.48	17.30	92.8	
6	T	Air	0.39	19.60	93.5	
Average					94.0	
7	L	Salt (3.5%)	0.37	14.3	63.8	1414 NF
	L	Salt (3.5%)	0.37	14.7	65.5	367 NF
	L	Salt (3.5%)	0.37	15.4	68.6	3945 NF*
	L	Salt (3.5%)	0.37	16.5	73.6	362 NF*
	L	Salt (3.5%)	0.37	17.5	78.0	1081 NF*
	L	Salt (3.5%)	0.37	18.75	83.6	1435 NF*
	L	Salt (3.5%)	0.37	19.8	88.3	390 NF*
	L	Salt (3.5%)	0.37	20.9	93.3	14*
8	L	Salt (3.5%)	0.43	12.1	60	1102 NF
	L	Salt (3.5%)	0.43	13.2	65	371 NF*
	L	Salt (3.5%)	0.43	14.2	70	11*
9	L	Salt (3.5%)	0.44	16.5	82.8	0.17
10	L	Salt (3.5%)	0.45	13.6	69.5	24
11	L	Salt (3.5%)	0.41	14.3	68.2	18

Estimated K_{Ii} level - 65

NF = No failure

*Previously tested at lower K_{Ii}

Table XVIII. Fracture Toughness of Titanium 6Al-4V "Tee" Extrusion (Solution-Treated at 1725°F for 30 Min, Water-Quenched, and Aged 1000°F for 4 Hours, Air-Cooled)

Spec No.	Grain Direction	Environment	Crack Length (a)	Load (lb)	K_I	Time to Failure (min)
1	L	Air	0.36	13.6	59.5	
2	L	Air	0.37	14.9	66.4	
3	L	Air	0.33	17.2	71.5	
Average					65.8	
4	T	Air	0.29	19.90	76.8	
5	T	Air	0.27	18.55	69.0	
6	T	Air	0.30	18.70	73.5	
Average					73.1	
7	L	Salt (3.5%)	0.37	12.0	44.6	693 NF
	L	Salt (3.5%)	0.37	12.5	46.5	1220 NF*
	L	Salt (3.5%)	0.37	13.8	51.3	1*
8	L	Salt (3.5%)	0.38	10.1	45.9	1106 NF
	L	Salt (3.5%)	0.38	11.2	50.9	4*
9	L	Salt (3.5%)	0.35	11.6	50.0	3
10	L	Salt (3.5%)	0.39	12.8	59.2	0.5
11	L	Salt (3.5%)	0.42	13.7	66.5	0.42

Estimated K_{Ii} level 46

NF = No Failure

*Previously tested at lower K_{Ii}

Table XIX. Fracture Toughness of Titanium 6Al–4V "Tee" Extrusion (Solution–Treated at 1725°F for 30 Min, Water–Quenched, and Aged at 1250°F for 4 Hours, Air–Cooled)

Spec No.	Grain Direction	Environment	Crack Length (a)	Load (lb)	K_I	Time to Failure (min)
1	L	Air	0.48	13.95	74.9	
2	L	Air	0.36	17.30	75.7	
3	L	Air	0.33	19.90	82.8	
Average					77.8	
4	T	Air	0.42	16.75	81.2	
5	T	Air	0.46	15.45	80.0	
6	T	Air	0.39	17.25	82.3	
Average					81.3	
7	L	Salt (3.5%)	0.39	13.9	53.6	1413 NF
	L	Salt (3.5%)	0.39	14.4	55.6	383 NF*
	L	Salt (3.5%)	0.39	15.6	60.3	3985 NF*
	L	Salt (3.5%)	0.39	16.8	64.9	361 NF*
	L	Salt (3.5%)	0.39	18.0	69.5	1091 NF*
	L	Salt (3.5%)	0.39	19.2	74.1	80*
8	L	Salt (3.5%)	0.38	12.5	56.8	1154 NF
	L	Salt (3.5%)	0.38	13.7	62.3	3*
9	L	Salt (3.5%)	0.26	18.8	68.7	0.25
10	L	Salt (3.5%)	0.40	13.2	61.9	13
11			0.30	16.4	64.4	3.5

Estimated K_{Ii} level 60

NF = No Failure

*Previously tested at lower K_{Ii}

			HEAT TREATMENT					
			Annealed - 1300°F for 2 Hours - Air Cooled				Solution Treated Water Quenched, A Hours - Air Coole	
Specimen	Grain Direction	Environment	Crack Length (a)	Load (lbs.)	K_I [1]	Failure (min.)	Crack Length (a)	Load (lbs.)
1	L	Air	0.30	11.55	83.5		0.31	9.80
2	L	Air	0.29	11.90	84.3		0.37	8.30
3	L	Air	0.35	10.35	82.2		0.34	7.86
Average					83.3			
4	L	Salt (3.5%)	0.37	8.50	70.0	1318 NF	0.36	6.31
		Salt (3.5%)	0.37	8.86	73.0	384 NF*	0.36	6.57
		Salt (3.5%)	0.37	9.80	80.7	3940 NF*	0.36	6.80
		Salt (3.5%)	0.37	10.3	85.0	360 NF*		
		Salt (3.5%)	0.37	10.9	90.0	1086 NF*		
		Salt (3.5%)	0.37	11.5	95.0	1 *		
5	L	Salt (3.5%)	0.37	9.11	75.0	4	0.31	6.79
		Salt (3.5%)					0.31	8.11
6	L	Salt (3.5%)	0.32	10.65	80.0	2	0.35	6.67

[1] Estimated K_{Ii} level 73
NF - No Failure
* - Previously tested at lower K_{Ii}

[2] Estimated K_{Ii}
NF - No Failu
* - Previous K_{Ii}

A

Table XX. Fracture Toughness of Titanium 6A1-4V Angle Extrusion

HEAT TREATMENT								
...re -	Solution Treated at 1725 F - 30 Min. - Water Quenched, Aged - 1000°F - 4 Hours - Air Cooled				Solution Treated - 1725°F - 30 Min. - Water Quenched, Aged - 1250°F - 4 Hours - Air Cooled			
...ure (min.)	Crack Length (a)	Load (lbs.)	K_I [2]	Failure (min.)	Crack Length (a)	Load (lbs.)	K_I [3]	Failure (min.)
	0.31	9.80	72.2		0.30	10.35	74.8	
	0.37	8.30	68.3		0.35	8.80	69.8	
	0.34	7.86	61.2		0.31	9.50	70.1	
			67.3				71.5	
...18 NF	0.36	6.31	51.0	956 NF	0.38	7.56	63.3	1364 NF
...84 NF*	0.36	6.57	53.0	2878 NF*	0.38	8.19	68.5	485 *
...40 NF*	0.36	6.80	55.0	1 *	0.38	8.82	73.8	945 *
...60 NF*					0.38	9.45	79.1	5 *
...86 NF*								
1 *								
4	0.31	6.79	50.0	1366 NF	0.40	8.75	75.8	0.75
	0.31	8.11	55.0	0.25 *				
2	0.35	6.67	52.8	2	0.32	9.50	71.3	0.5
...at lower	[2] Estimated K_{Ii} level 51 NF - No Failure * - Previously tested at lower K_{Ii}				[3] Estimated K_{Ii} level 70 NF - No Failure * - Previously tested at lower K_{Ii}			

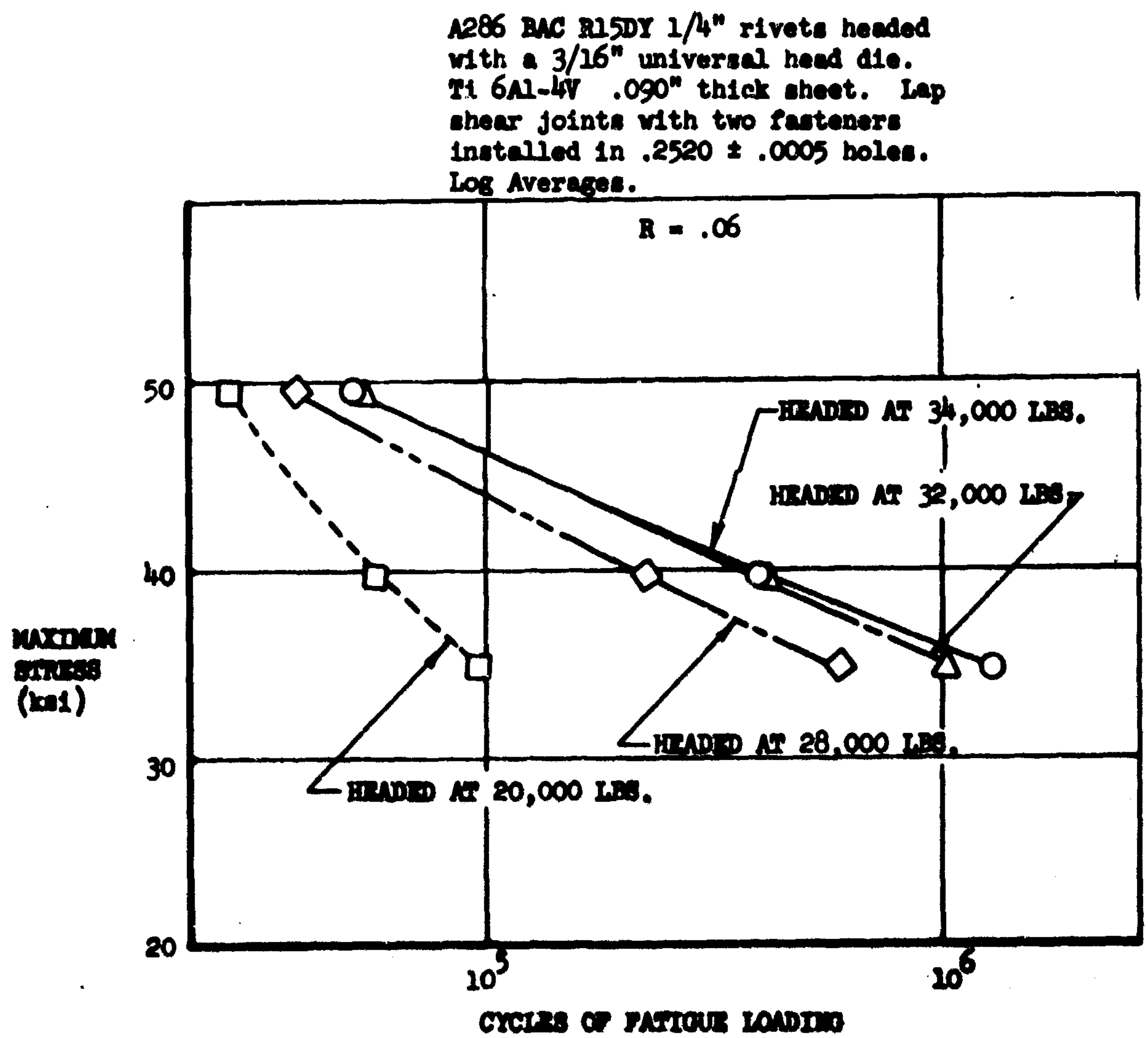


Figure 33. Cycles of Fatigue Loading Heading Force Study, A286 Rivets

A286 BAC R15DY 1/4" rivets headed with a 3/16" universal head die.
Ti 6Al-4V .090" thick sheet.
Lap shear joints with two fasteners installed in .2520 ± .0005 holes.

R = .06

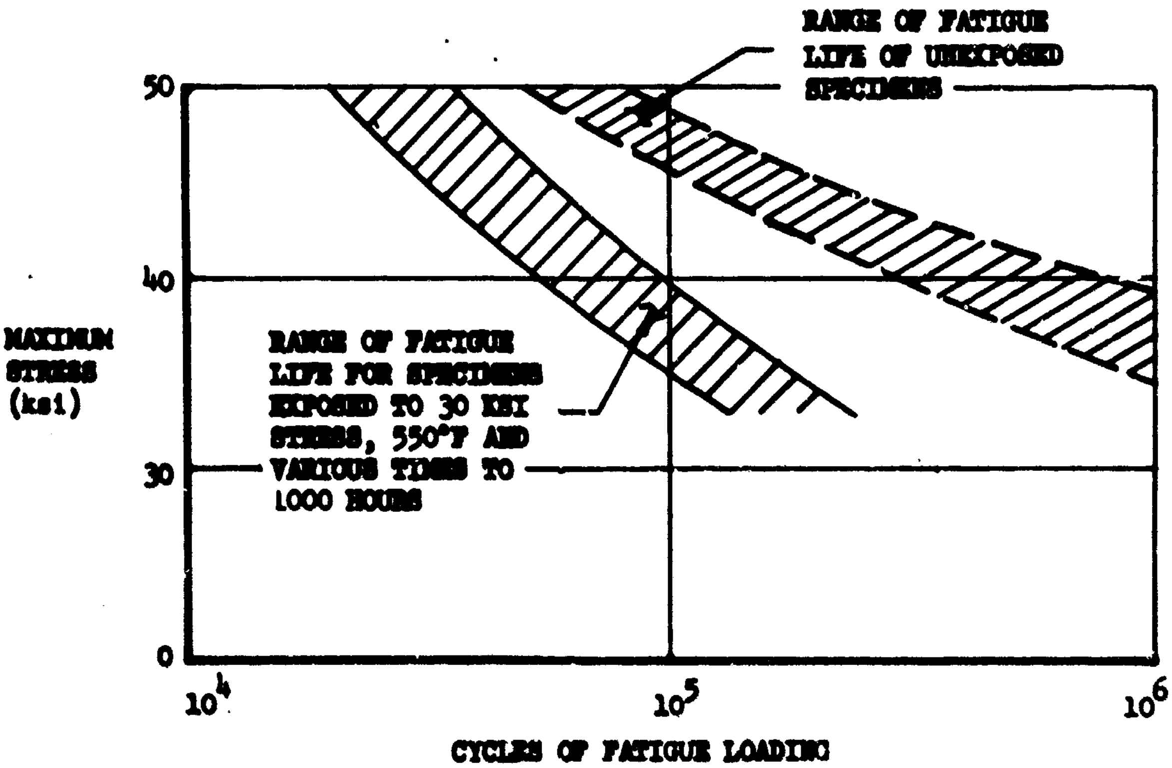


Figure 34. Exposure Study, A286 Rivets

Ti 6Al-4V .090" thick sheet joined with 1/4" dia. A286 BAC R15DY rivets. Lap shear specimens. Rivets compression headed at 32,000 lbs. with a 3/16" universal head die.

R = .06

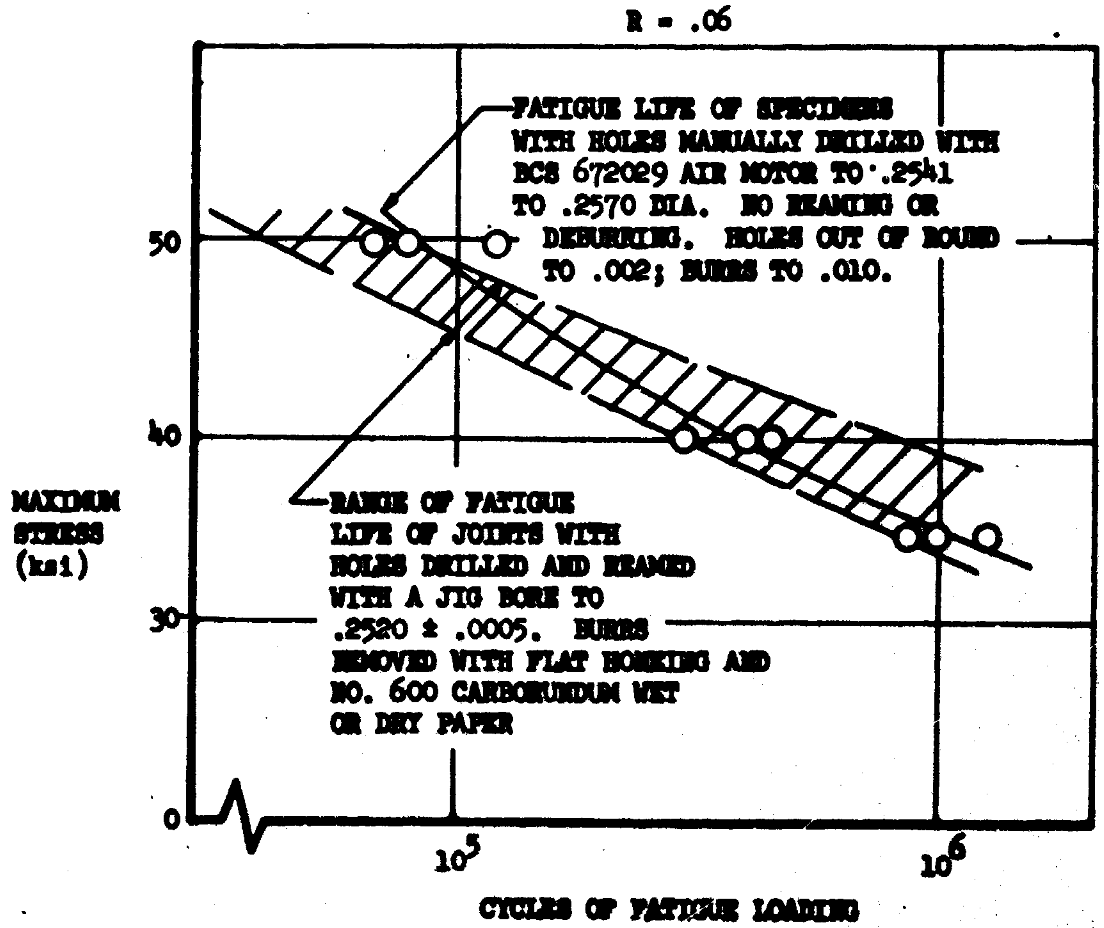


Figure 35. Hole Study Manually-Drilled Vs. Precision-Holes, A286 Rivets

III. Description of Technical Progress (continued)

1008. Materials and Processes (continued)

Bolt and Nut Evaluation

The torque-tension relationships for various bolt-nut combinations have been determined. Figure 36 illustrates typical data obtained on 1/4-, 5/16-, and 3/8-in. diameter bare Ti 6Al-4V bolts assembled with corrosion-resistant nuts coated with a high-temperature dry-film lubricant, Lubeco 2123. Figure 37 shows the torque-tension relationship on 1/2-in. diameter Ti 6Al-4V bolts with dry film lubricated CRES nuts. Figure 38 illustrates typical data for bare Ti 6Al-4V bolts assembled with A286 corrosion-resistant nuts having two different dry-film lubricants, Lubeco ±2123 and Esnalube 382. Tests are in progress to determine the effect of 500°F exposure on the torque-tension relationship of the above parts.

A test program is in progress to evaluate fatigue properties of Taper Lok-fastened joints subjected to a time-temperature-stress environment. Single-shear lap joints of 0.090-in. thick 6Al-4V titanium sheet, fastened by two Taper Lok fasteners, were soaked 500 hr at 425°F and at 500°F while loaded under 30,000 psi gross area stress. Preliminary data, shown in Table XXI, indicates a slight reduction in fatigue life due to the elevated temperature soak under stress. Additional tests are planned to evaluate the effects of joint configurations and longer exposure times on fatigue behavior.

Table XXI. Fatigue Properties of Exposed Taper Lok–Fastened Joints

Specimen Number	Condition	Fatigue Cycles to Failure [1]
T127	As assembled,	35,000
T128	no exposure	40,000
T129	to high	40,000
T130	temperature	41,000
T131		38,000
Log Average		38,750
TLN41	Exposed to 425°F	35,000
TLN42	for 500 hr at	38,000
TLN43	a load of 30,000	29,000
TLN44	psi	34,000
TLN45		40,000
TLN46		32,000
TLN47		38,000
TLN48		34,000
TLN49		34,000
TLN50		40,000
Log Average		35,240

[1] Maximum Stress = 40,000 psi (gross area)
R = 0.06 Room Temperature

1008. Materials and Processes (continued)

Table XXI (Concluded)

Specimen Number	Condition	Fatigue Cycles to Failure [1]
TL1	Exposed to 500°F	30,000
TL2	for 500 hours at	32,000
TL3	a load of 30,000	36,000
TL4	psi	37,000
TL5		34,000
Log Average		33,700

[1] Maximum Stress = 40,000 psi (gross area)
R = 0.06 Room Temperature

Fusion Welding

Panels of 0.250-in. thick annealed Ti 6Al-4V plate were fusion-welded by the gas-shielded tungsten arc (GTA) and dual gas-shielded tungsten-arc (DGTA) processes. The GTA welds were made with Ti 6Al-4V, Ti 5Al-2.5Sn, and commercially pure filler metal. The DGTA welding process employed no filler material. All panels were stress-relieved subsequent to welding. Preliminary data summarized in Table XXII show that panels welded with Ti 6Al-4V filler wire have the highest strength, but that Ti 5Al-2.5Sn weldments exhibit the best ductility. Similar panels of 0.250- and 0.500-in. thick Ti 6Al-4V will be evaluated for bend ductility and slow-bend-notch toughness.

In-place, butt, fusion-welded joints have been prepared in 1/2-in. diameter x 0.015-in. wall AISI Type 321 and 1/2-in. diameter x 0.042-in. wall Ti 3Al-2.5V tubing, using AISI Type 347 and Ti 6Al-4V inserts, respectively. The insert configurations were developed to control the extent and contour of the underbead and to provide filler metal to the joint without the use of the melt-through sleeve. The joints were satisfactory based upon visual and metallurgical examination, and representative specimens are currently being fatigue tested.

1009. Mockups

The engineering review on the forebody and crew compartment mockup has been conducted, and the mockup is being revised as a result

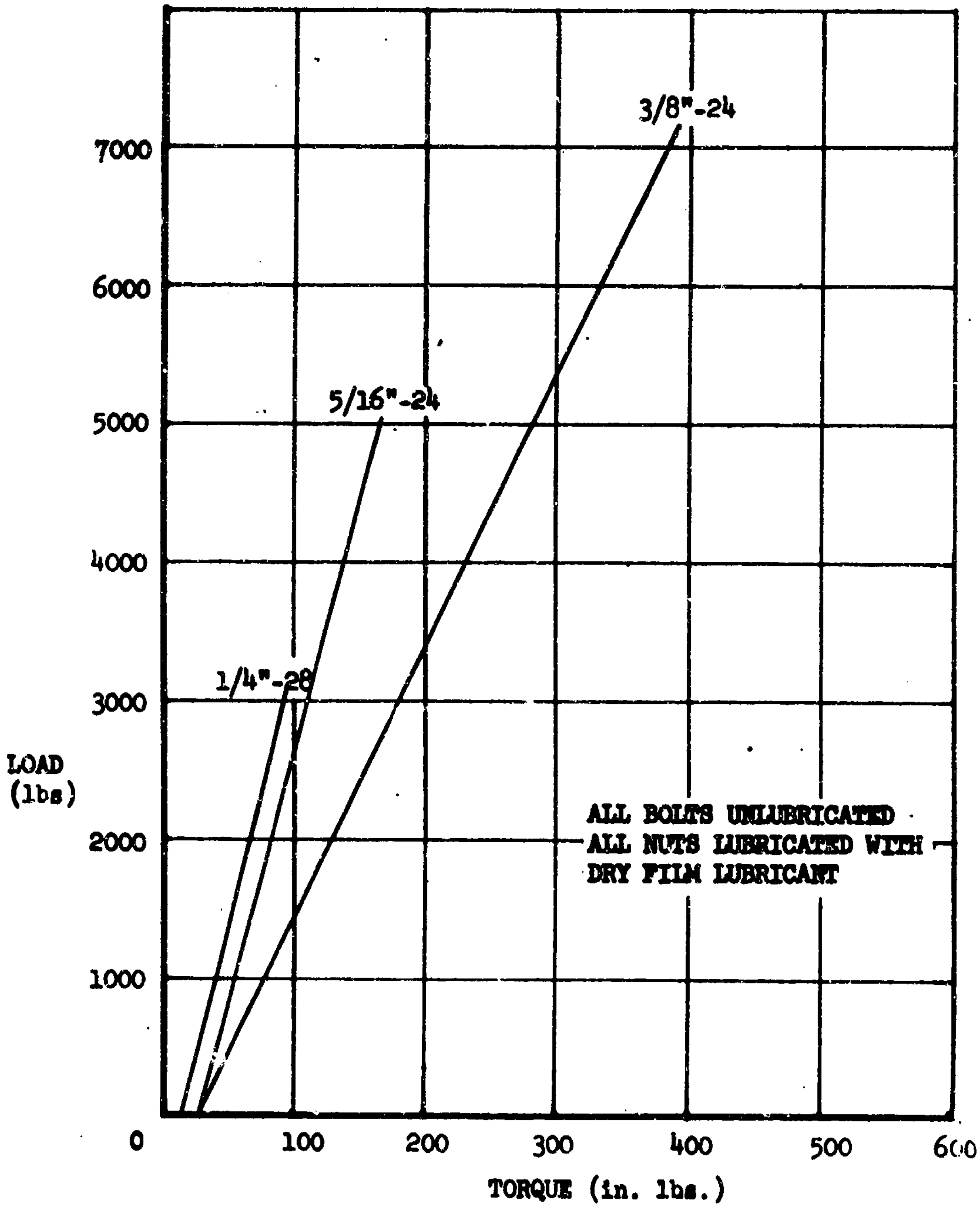


Figure 36. Torque–Tension Curves for Titanium Bolts With Cres Nuts

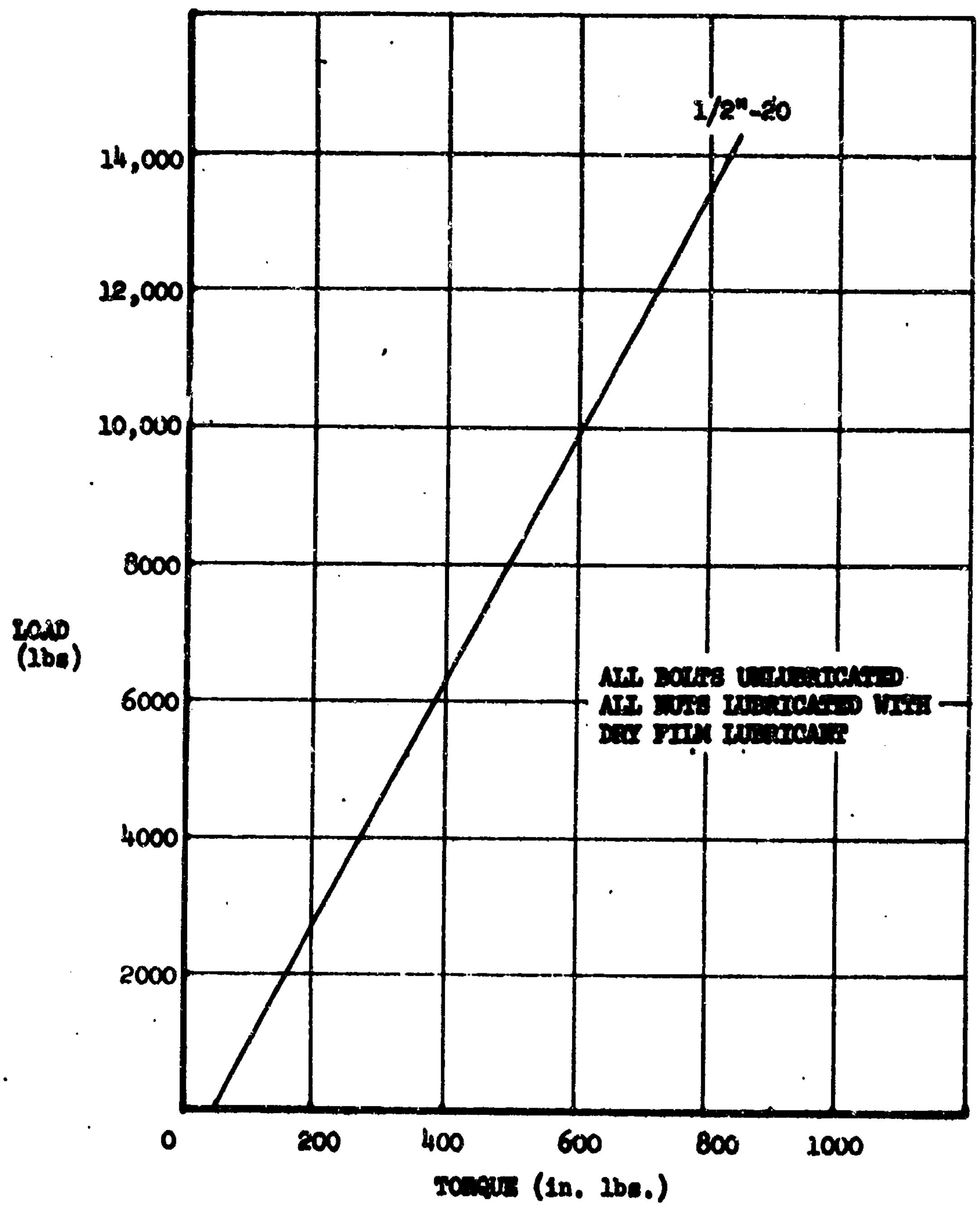


Figure 37. Torque–Tension Curves for Titanium Bolts With Cres Nuts

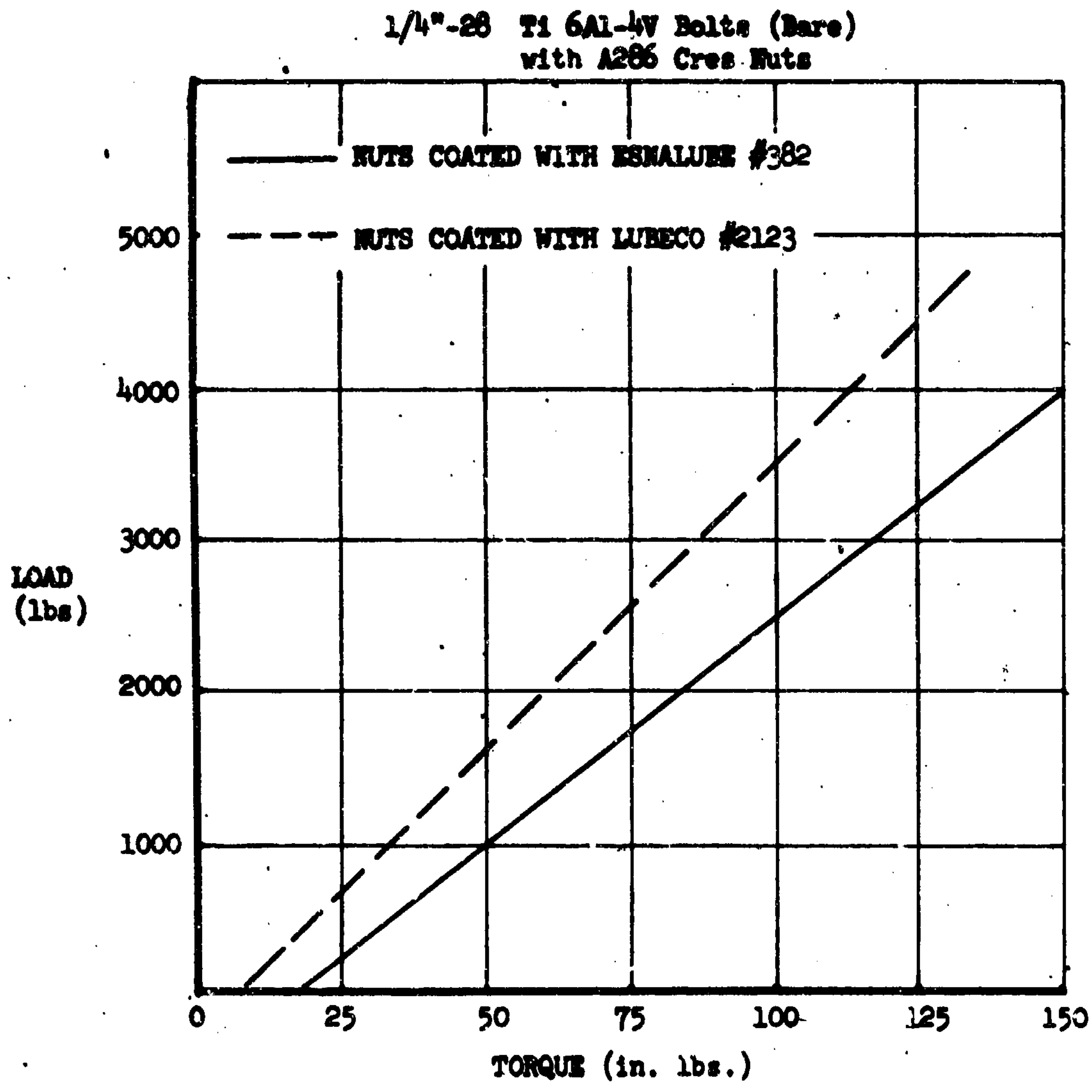


Figure 38. *Torque–Tension Curves for Lubricant Evaluation–Titanium Bolts With A 286 Nuts*

Table XXII. Room Temperature Tensile Test of Welded 0.250-In. Ti 6Al-4V

Specimen Type	Filler Wire	Stress F_{tu} (ksi)	(ksi) F_{ty} (ksi)	Elong(%) 1"	Elong(%) 2"	Reduction in Area (%)	Joint Effic'y (%)	% Weld to BM	Fracture Location
Base metal	None (Grain long.)	140	133	20.5	16				
Base metal	None (Grain transv)	146.2	140.9	20.4	15	24.4			
Longitudinal welds	Ti-5Al-2.5Sn	145.3	138.3	15	12	14.6	99.3	35%	Reduced section
Transverse welds	Ti-5Al-2.5Sn	137.9	129.3	12.4	8	18.2	94.3		
Longitudinal weld	None	142.1	133.0	12.5	9		100.9	54%	Reduced section
Transverse weld	None DGTA	149.2	143.8	16	11		106.0		2 Spec at weld edge 3 Spec in base mat'l
Longitudinal weld	Ti-6Al-4V	153.1	139.7	7.2	7		108.8	89%	Reduced section
Transverse weld	Ti-6Al-4V	142.7	132.3	2.6	5.6		101.4		Parent mat'l
Longitudinal weld	Ti Comm. pure	140.8	130.8	13.8	11.8		100.1	37%	Reduced section
Transverse weld	Ti Comm. pure	127.9	111.8	8.2	4		90.9		Weld

NOTES: Average of 5 specimens

Mill-annealed base metal + GTA weld + stress relief

1009. Mockups (continued)

of the review. Refer to Par. 1104 for more detailed information on this mockup.

Construction of the following mockups is in work, with completion scheduled for September 1, 1966.

- Electrical/Electronics Racks
- Power Plant Installation
- Wing Pivot

Construction of the Class I Mockup is on schedule. As of July 22, the fuselage was 90 percent complete, the wing 62 percent complete, the empennage 86 percent complete, and the interior of the passenger compartment 55 percent complete. Figures 39 and 40 show the current status of the interior and exterior of the mockup. The flight deck mockup was completed on schedule and is shown in Figs. 41, 42, and 43. The mockup is now available for use by government, airline, and Boeing personnel in evaluating flight deck arrangement and crew vision characteristics. Engine mockups have been received from General Electric and Pratt & Whitney, as shown in Figs. 44 and 45. Power pack buildup has begun and is on schedule.

1012. Flight Test Program

An evaluation of the Airborne Integrated Data System (AIDS) as a potential flight test instrumentation system was completed. The results are that the AIDS will be used to obtain the type of data for which it was designed but it will not be used to obtain performance data during the flight evaluation of the airplane.

Features of AIDS compared with flight test instrumentation requirements were: capacity, sampling rate, data compression techniques, frequency response, type recording. transducers accuracy, and state of development. The AIDS system lacked capability in sampling rate, data compression response, accuracy, and state of development.

This will fulfill the requirements for Detail Work Plan item (2130).

During the past two months, all flight test documentation relative to the SST program has been updated and released. Among the documents released was the Flight Test Data System Specification, D6-19167-1 (Acquisition and Recording Subsystem). The document describes the sensing, conditioning, recording, and safety monitoring equipment to be used during the flight test program. Included is a functional description of all line recording systems (airborne, telemetry, or ground).

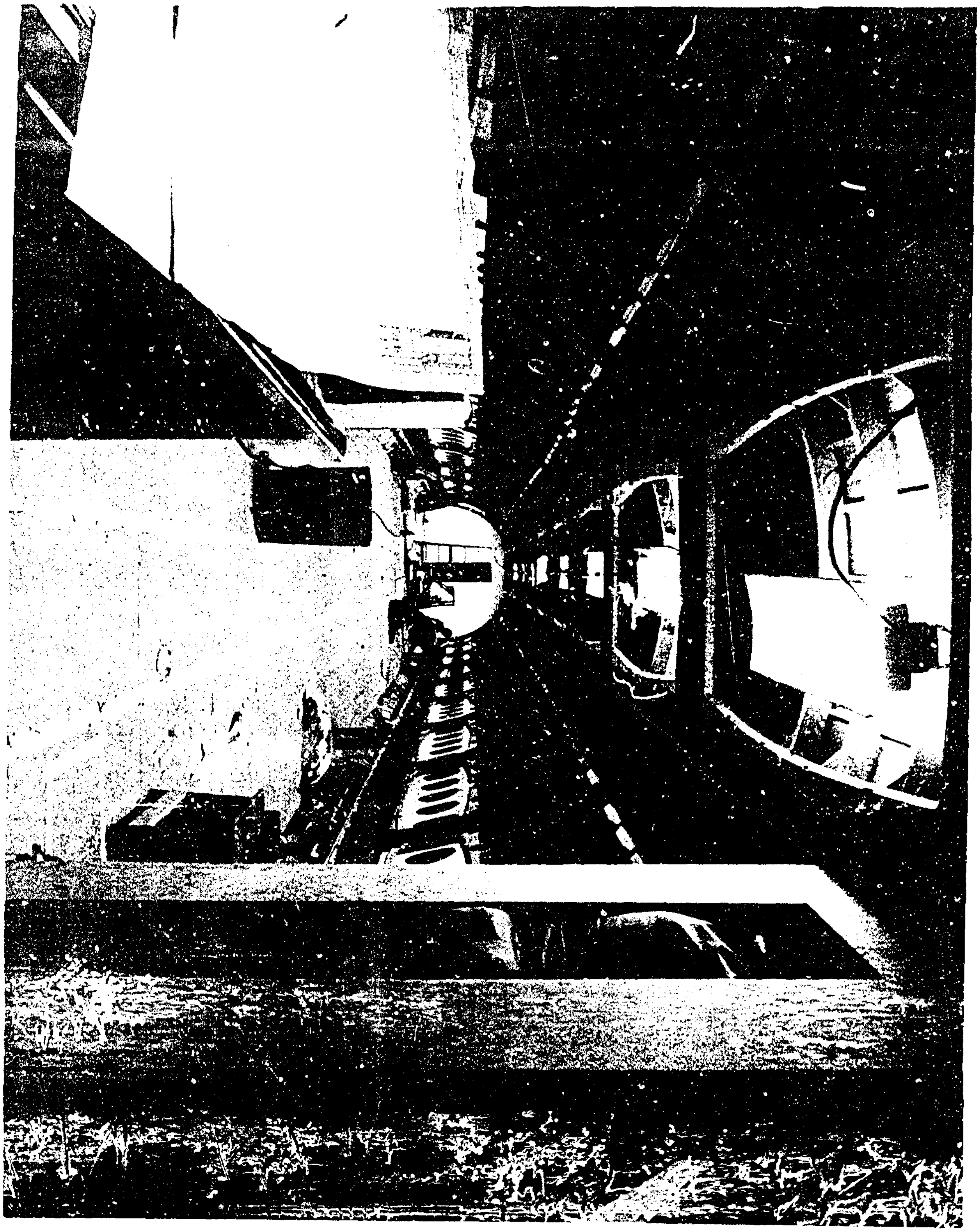


Figure 39. Full Scale Class I Mockup – Passenger Cabin Interior

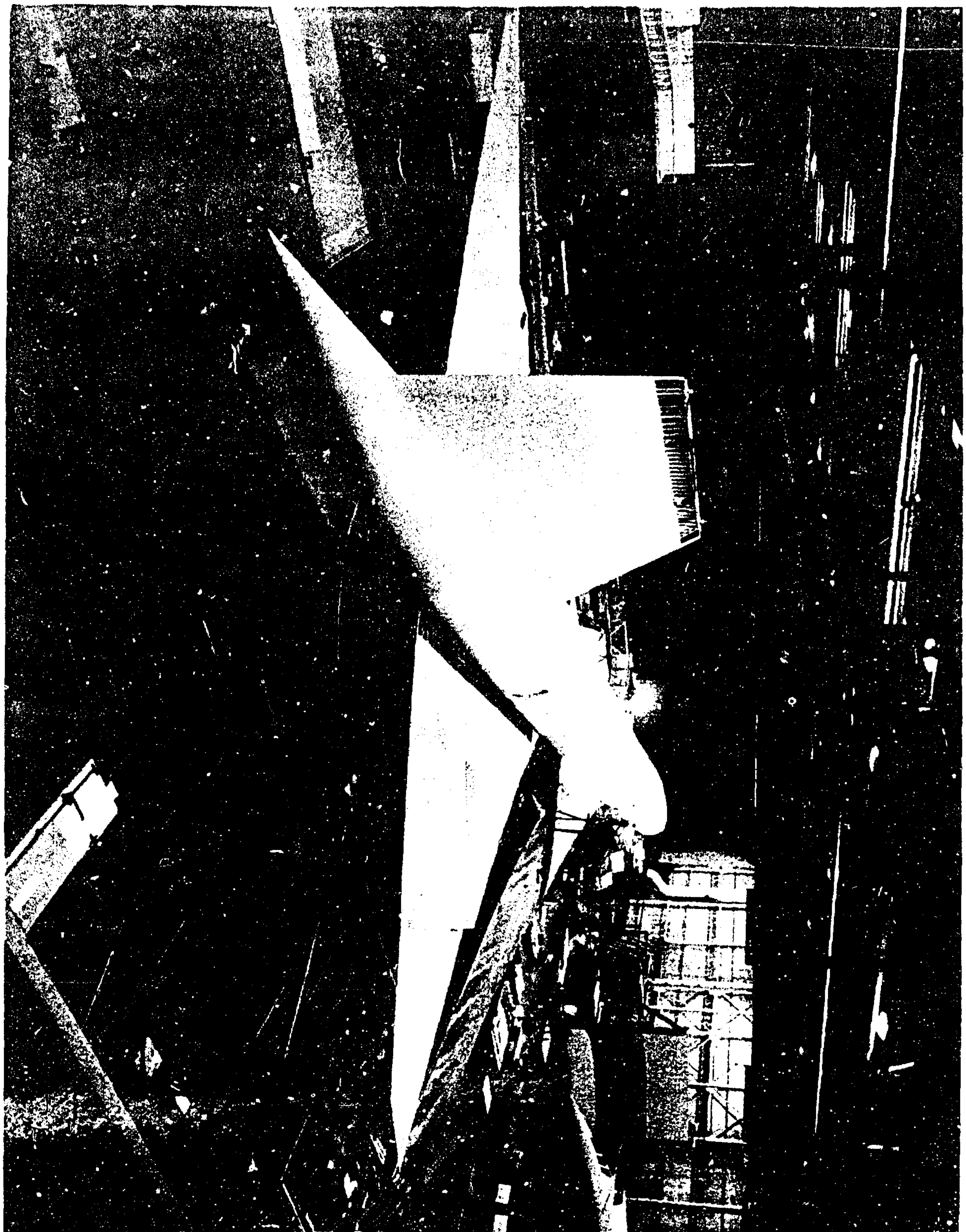


Figure 40. Full Scale Class I Mockup – Rear View

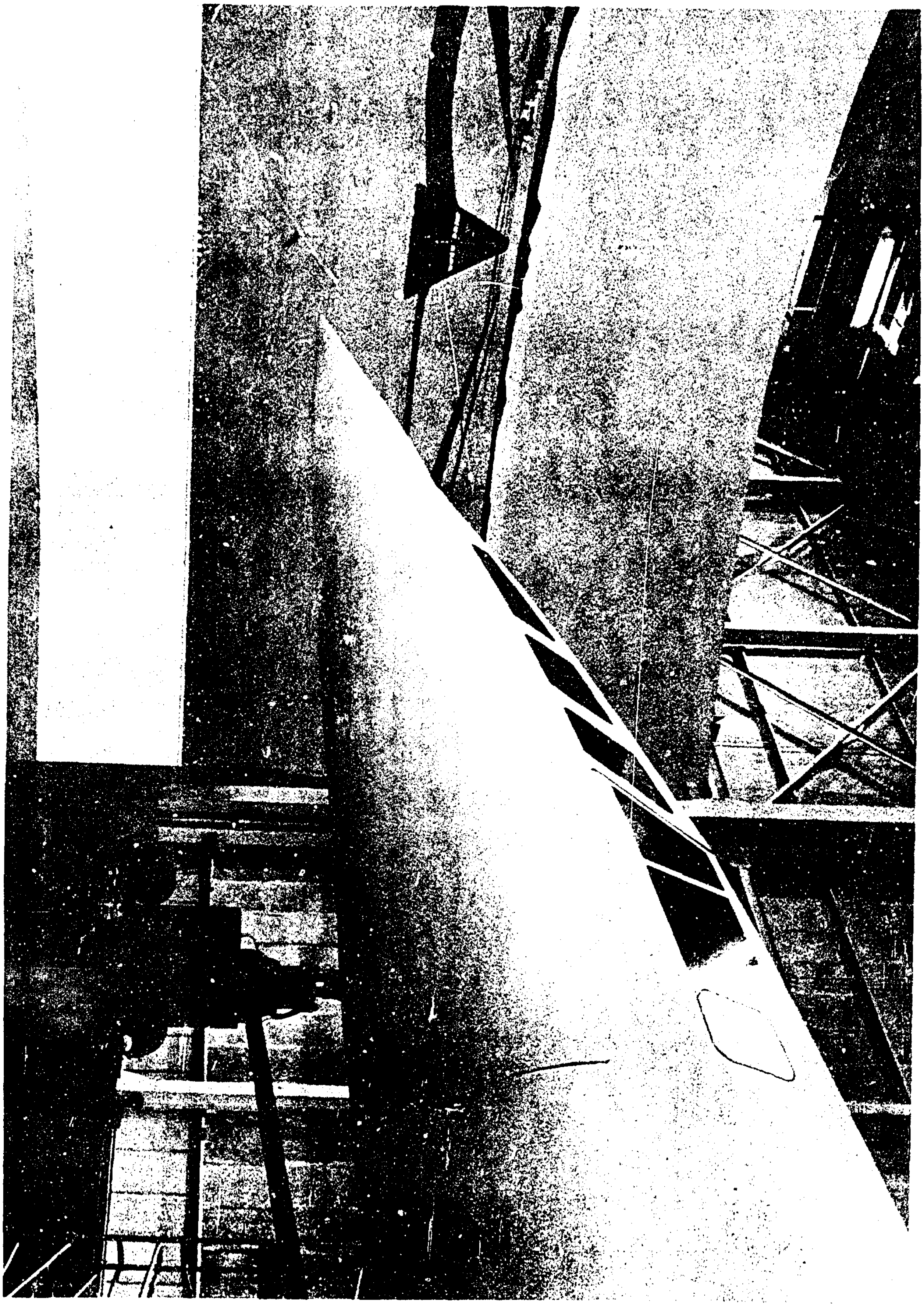


Figure 41. Full Scale Class I Mockup – Nose

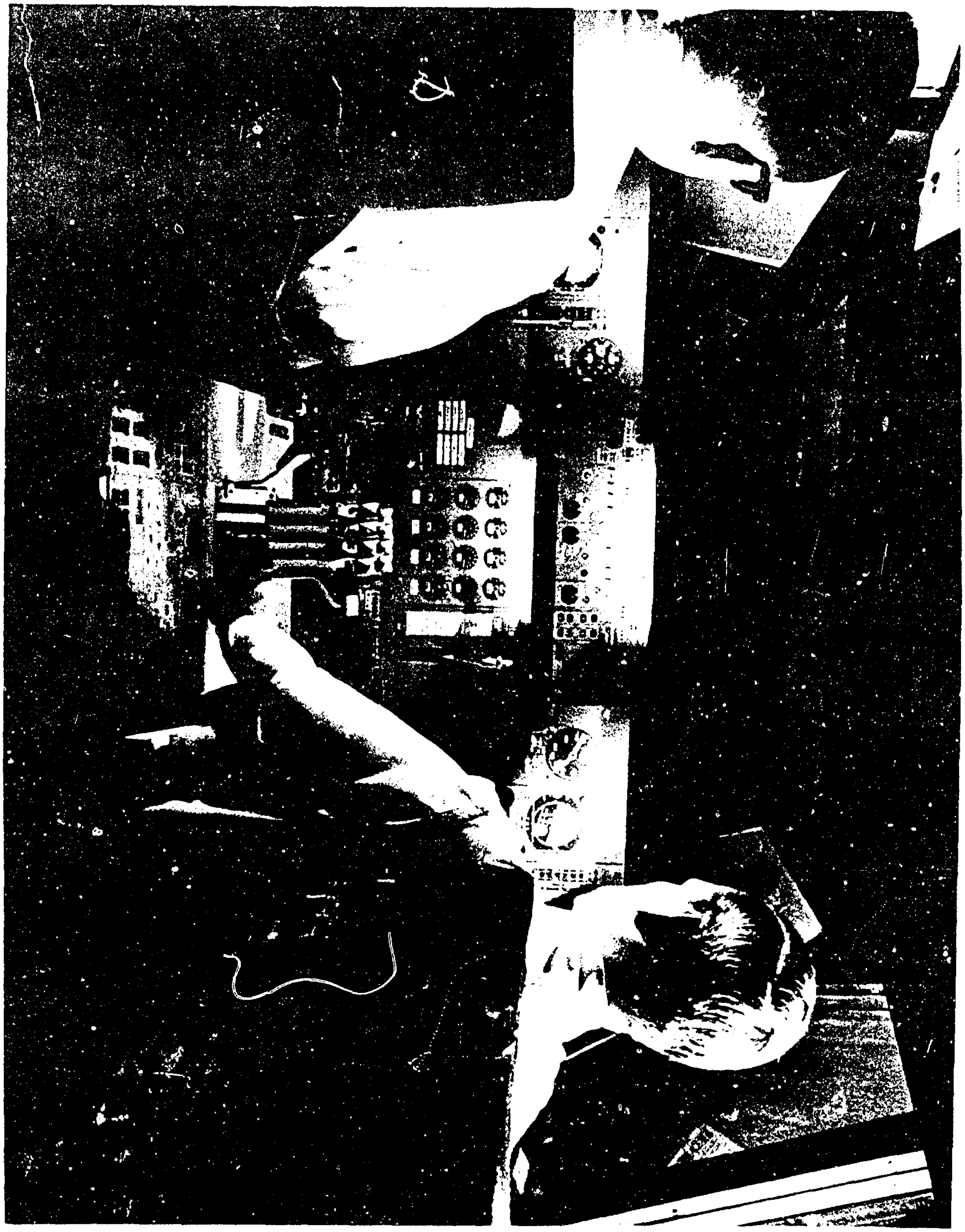


Figure 42. Full Scale Class I Mockup – Pilot's Compartment

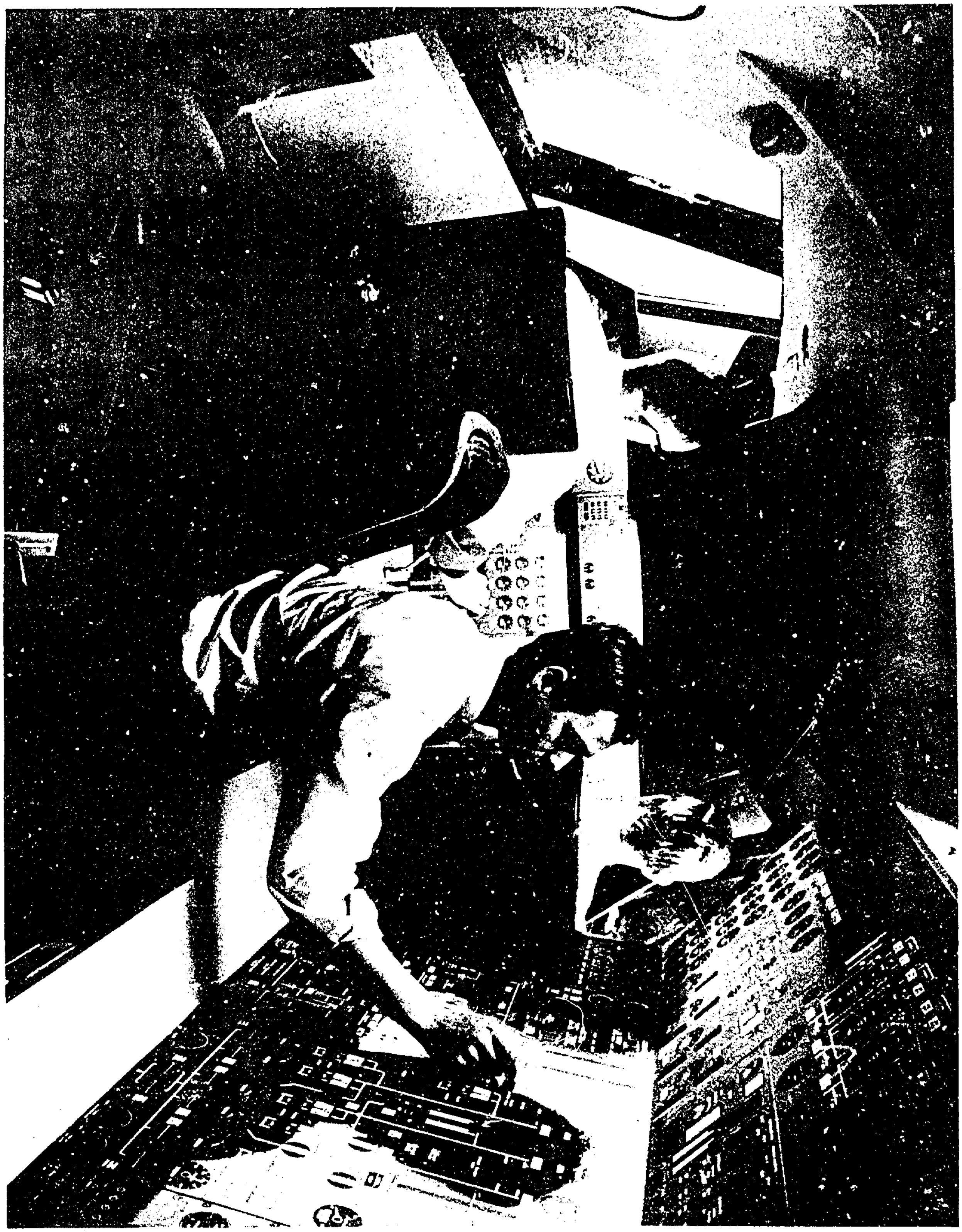


Figure 43. Full Scale Class I Mockup – Crew Compartment

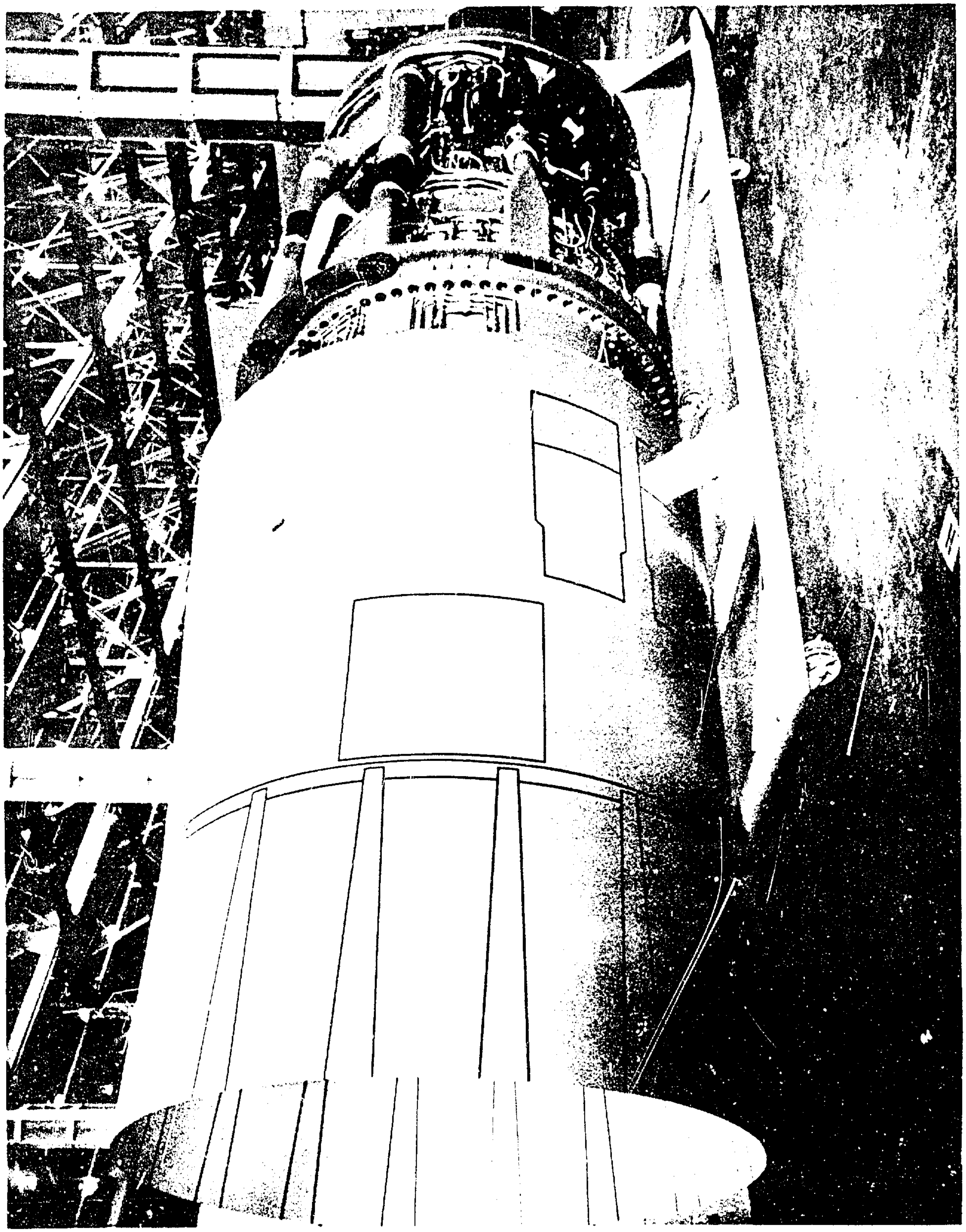


Figure 44. Full Scale Class I Mockup – P&W Engine

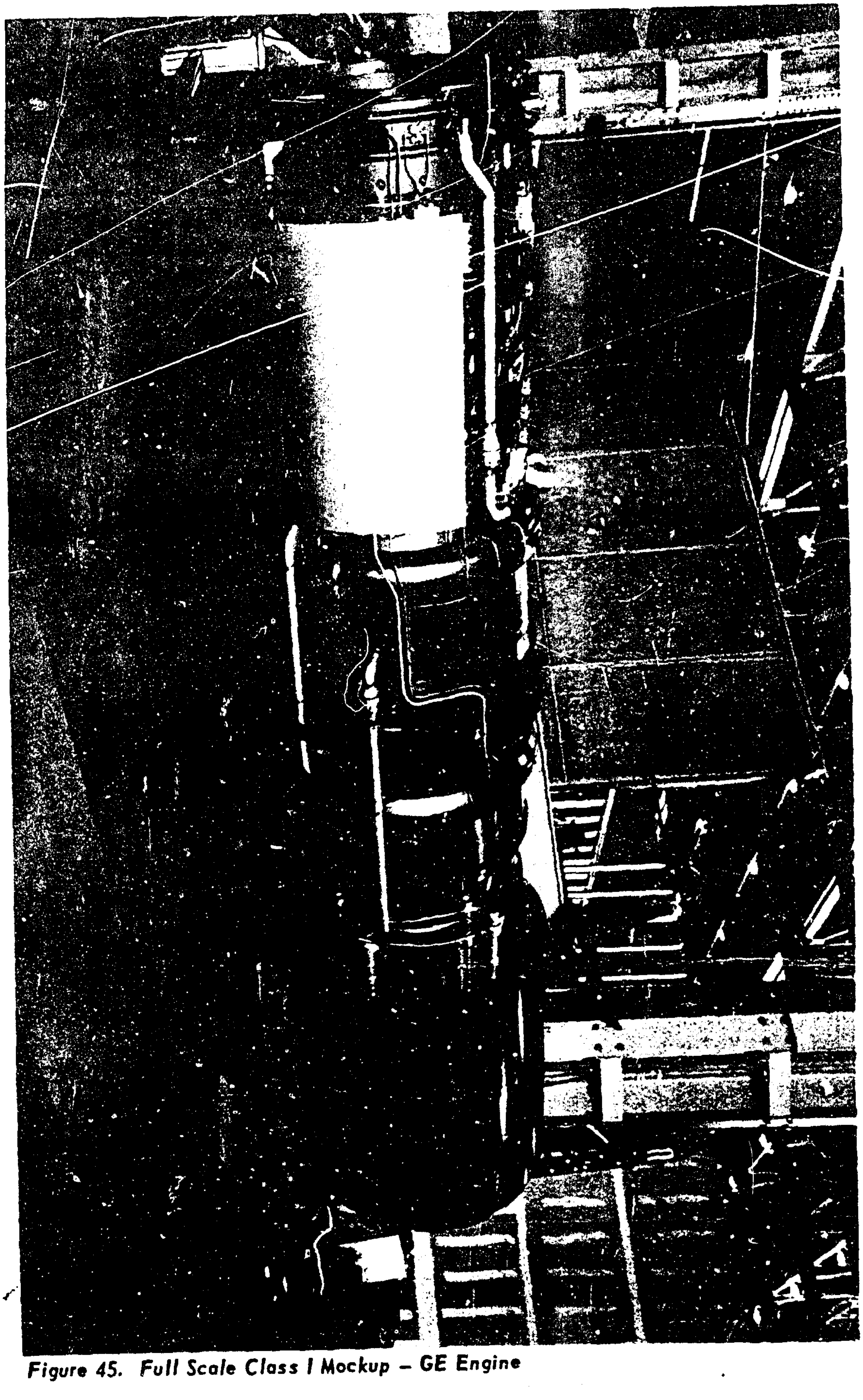


Figure 45. Full Scale Class I Mockup – GE Engine

III. Description of Technical Progress (continued)

1012. Flight Test Program (continued)

Release of this document fulfilled the requirement for Detail Work Plan item (2138).

A preliminary design review was conducted for the flight test data system airplane installation. Material presented covered descriptions of the various components associated with the airborne data acquisition system, a discussion of the sensors to be used, and test wire routings. The general layout for the data system will be as illustrated in Figs. 46 and 47. Specific details of the system are contained in D6-19167-1.

1013. Standardization

The Standardization Unit has completed the Phase III Standardization Program, V4-B2707-19. This program was completed on schedule.

Fifty-six supplier bid proposals have been reviewed by the unit during this report period to determine the adequacy of their standardization program.

Material and process specifications that apply to the SST Program are being reviewed for inclusion in program documentation.

1014. Quality Control

Plating Bath Hydrogen Control

The limits upon hydrogen picked up by high-strength steels during plating operations are critical. The limited hydrogen picked up during plating operations is removed by baking. In some cases, because of improper preparation and controls, the hydrogen cannot be driven out. This requires the parts to be recalled, stripped, and replated.

The principle problem is that it takes many hours of testing to determine if excessive hydrogen is contained in the parts. This present test is costly and time-consuming. Production stoppages can occur while parts are recalled and reprocessed.

Quality Research and Development is incorporating the Lawrence Hydrogen Gage into shop areas for process control of hydrogen. The Lawrence Hydrogen Gage has the capability of giving results within 30 minutes after completing the plating operation.

The results of this program will be published in approximately two months. Successful results will provide large cost savings, both from the present expensive time-test method and costly production stoppage.

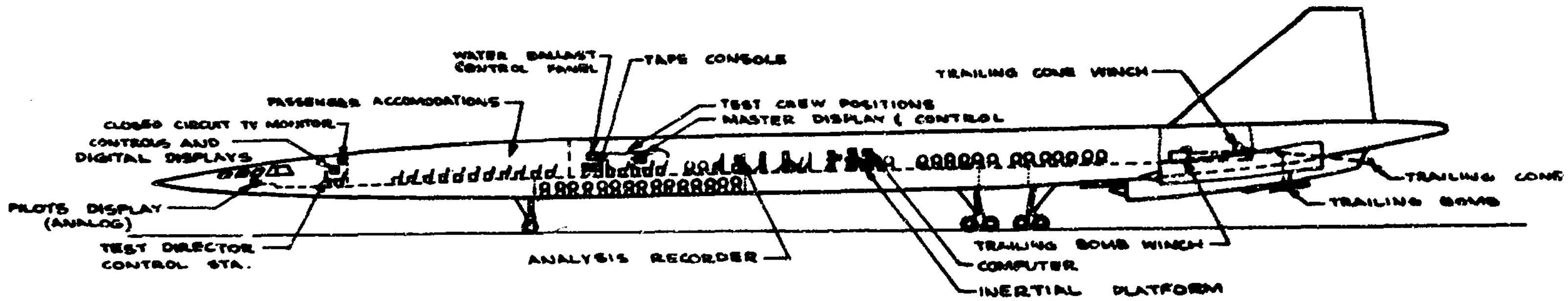


Figure 46. Instrumentation Arrangement (Side View)

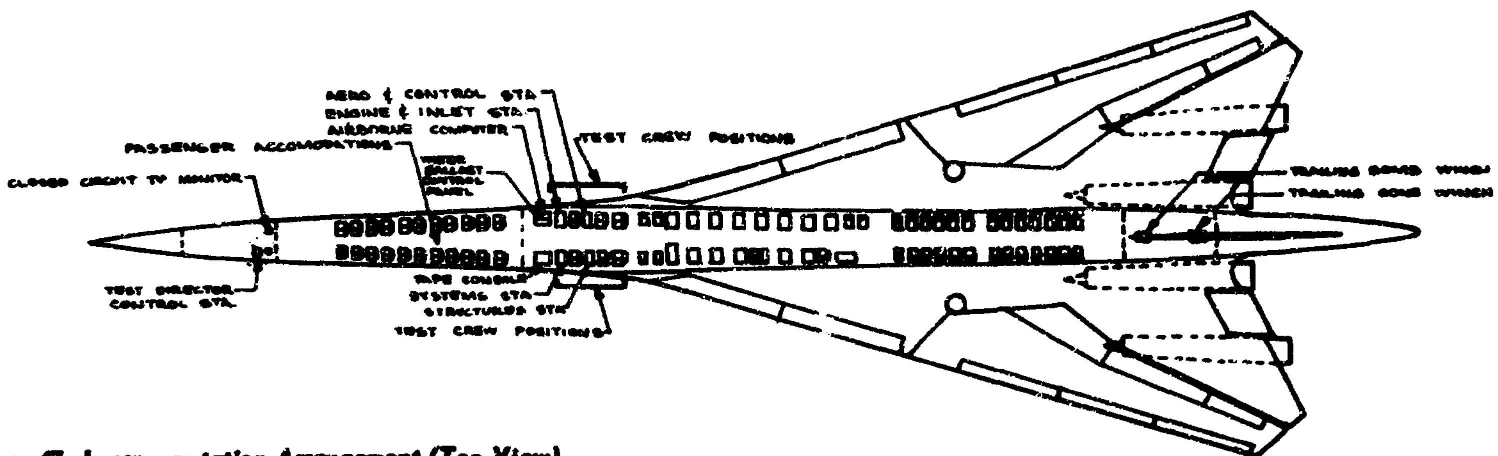


Figure 47. Instrumentation Arrangement (Top View)

1014. Human Engineering

Proposal Documentation

The Human Engineering and Life Support Program Plan, V4-B2707-8, has been completed and is currently in final review.

HE Requirements Analysis and Studies

The preliminary SST Task Analysis has been completed and the resulting data incorporated into a Flight Deck Crew Workload Analysis. Both of these studies will be incorporated in Document D6A10280-1, SST Flight Deck Crew Tasks and Equipment Analysis, which is scheduled for internal release in August. A Control and Display Evaluation is in work and scheduled for completion early in Phase III. The latter study will also be incorporated in D6A10280-1.

The Human Engineering data analysis and report preparation for D6A10252-1, Evaluation of B2707-SST Visual Field by Simulated Cruise, has been completed and is in final review prior to internal release in mid-August.

Document D6A10254-1, SST Vision Studies - Light Transmission, Reflections, and Glare, is in final typing prior to release.

Human Engineering data analysis for the visual approach and landing simulation study is continuing and is about 30 percent completed. The results will be incorporated in D6A10252-2, Evaluation of B-2707 - SST Visual Field by Simulated Cruise and Landing, scheduled for release in late August.

Design Support

The above documents establish the HE requirements to be incorporated by the design groups.

Fifty-six supplier proposals (relating to 21 equipment procurement items) to determine the effectiveness of their Human Engineering programs have been reviewed during this report period.

11. AIRFRAME STRUCTURE

1100. Airframe Structure, General

11001. TITANIUM ALLOY DEVELOPMENT PROGRAM

Metallurgical Stability of Ti 6Al-4V and Ti 4Al-3Mo-1V Stability Data for Exposures

Stability data for exposures to 5000 hours have been obtained for selected heat-treat conditions of Ti 6Al-4V and Ti 4Al-3Mo-1V. Exposure was at 450°F or 550°F under a constant 25-ksi stress. The data collected to date appears in Table XXIII. Small changes in mechanical properties due to exposure have occurred in all heat-treat conditions for both alloys. Property changes versus exposure time to 5000 hours are plotted in Figs. 48 and 49 for two thermal conditions. The only significant exposure effect is the variation of the K_{Ic} value with exposure time for the Beta-STA-1250 Ti 6Al-4V (Fig. 48). This variation will be further evaluated by testing tensile and notched-bend specimens fabricated from the failed specimens of the 1000-hr and 2500-hr exposure tests. The K_{Ic} level, after an exposure of 10,000 hr, will also aid in evaluating this variation.

Table XXIII. Effect of Time, Temperature, and Stress on the Stability of Ti-6Al-4V and Ti-4Al-3Mo-1V.

Exposure	UTS (ksi)	YS (ksi)	Elong. (% 1")	RA (%)	K_{IC} (ksi in.)	K_{Ii} (360 min) (ksi in.)
Ti-6Al-4V Beta-STA-1250						
none	155.0	140.5	8	16	87.9	81
450°F 895 hr	157.7	142.6	6	17	111.0	84
550°F 911 hr	159.9	146.6	5	14	120.1	83
450°F 2523 hr	154.4	140.6	7	17	113.1	88
550°F 2504 hr	157.1	141.6	7	16	122.8	90
450°F 5000 hr	161.6	144.7	7	9	92.6	76
Ti-6Al-4V Beta-STA-1000						
none	164.6	149.9	7	11	93.3	56
450°F 902 hr	175.5	160.2	5	13	92.3	75
550°F 911 hr	177.5	160.8	5	10	83.0	69
450°F 2523 hr	173.9	158.9	5	7	87.7	77
550°F 2504 hr	172.8	154.6	5	9	87.3	71
Ti-6Al-4V Duplex Anneal						
none	148.8	142.1	14	38	75.0	56
450°F 1000 hr	151.0	142.9	15	38	78.4	59
550°F 1000 hr	156.5	145.2	12	35	79.9	42
450°F 2500 hr	154.9	145.8	13	36	78.2	56
550°F 2500 hr	158.6	145.9	13	33	74.0	54
Ti-4Al-3Mo-1V Beta-STA-1150						
none	154.8	137.2	7	16	96.3	77
450°F 1000 hr	161.7	140.7	7	17	85.6	67
550°F 1000 hr	163.0	141.2	5	15	78.2	66
450°F 2500 hr	165.6	144.9	6	14	86.6	63
550°F 2500 hr	163.0	140.1	6	15	83.3	66
450°F 5000 hr	163.4	142.3	7	15	81.7	63
Ti-4Al-3Mo-1V Beta-STA-1050						
none	175.0	154.5	4	10	75.9	64
450°F 1000 hr	181.5	156.3	4	10	61.7	49
550°F 1000 hr	177.9	150.3	4	10	64.9	56
450°F 2500 hr	182.1	154.8	4	9	63.9	56
550°F 2500 hr	179.9	152.6	5	11	75.2	54
Ti-4Al-3Mo-1V Duplex Annealed						
none	138.0	126.2	54	18	124.9	120
450°F 1000 hr	133.5	124.0	53	17	119.7	117
550°F 1000 hr	133.1	124.7	51	16	112.8	107
450°F 2500 hr	134.4	124.6	52	17	120.9	110
550°F 2500 hr	134.4	124.9	51	17	123.7	105

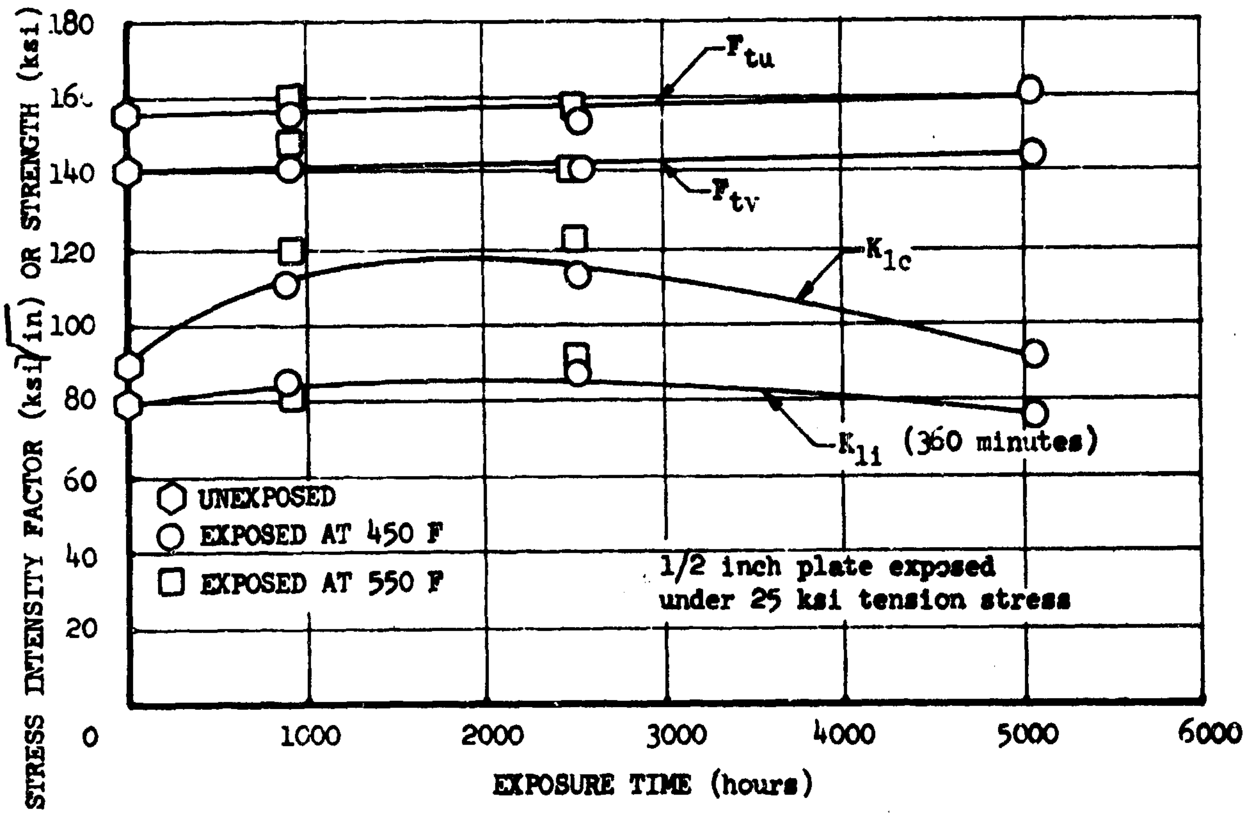


Figure 48. Stability of Ti 6Al-4V, Beta-Sta-1250

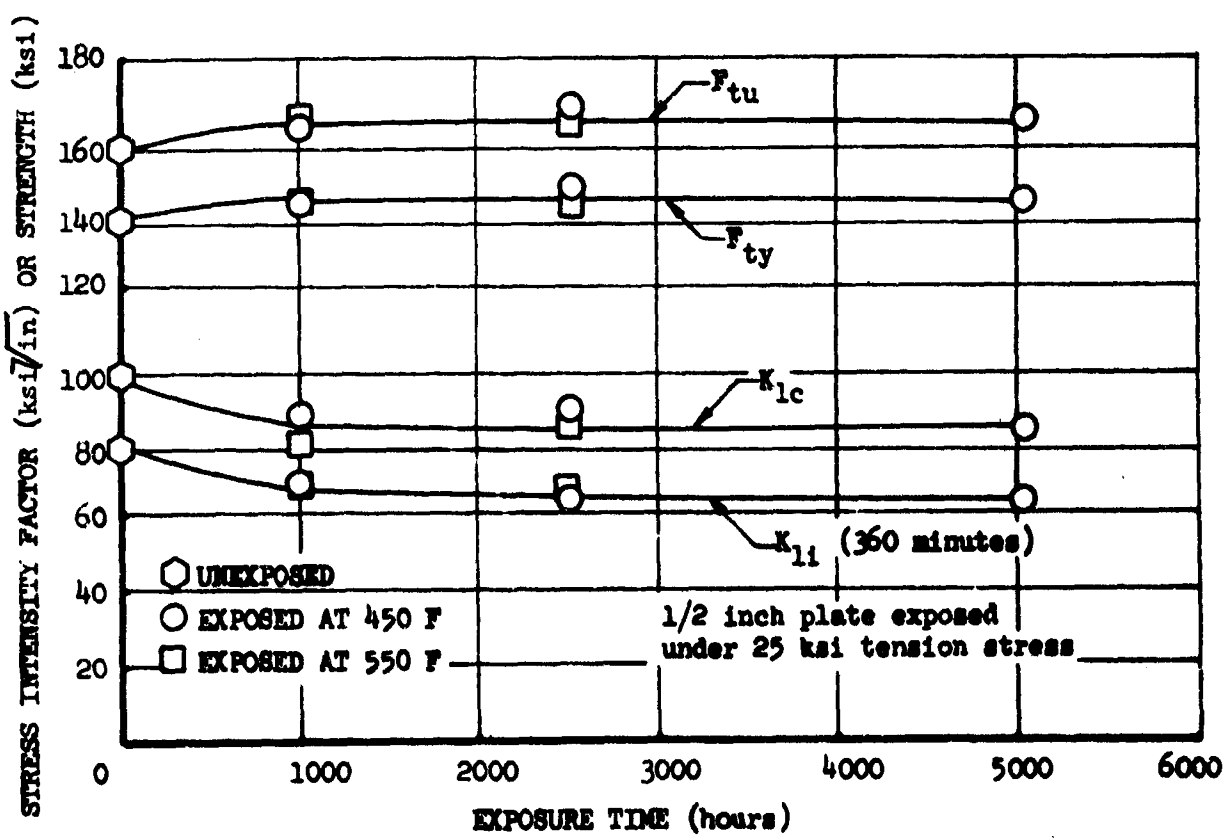


Figure 49. Stability of Ti 4Al-3Mo-1V, Beta-STA-1150

III. Description of Technical Progress (continued)

11001. Titanium Alloy Development Program (continued)

10,000-hr exposures of Beta-STA-1250 Ti 6Al-4V and Beta-STA-1150 Ti 4Al-3Mo-1V are in progress.

It has been established that the thermal resistant variations and effects on titanium alloys varies batch to batch. Data shows complete compatibility of 94-002 to the B-2707 simulated cycling environment for 5000 hours; however, additional test panels reveal various service life ranges of 1300 to 3000 hours. The main considerations to be obtained from the development work performed at the Air Force Material Laboratory, Dow Corning, Boeing, and other aircraft supporting facilities is that the basic chemistry of the fluorosilicone elastomers possesses necessary chemical characteristics to exceed the B-2707 environment and service life requirements.

The possible cause of these variations is attributed to: Impurities in synthesis and compounding ingredients, impurities introduced by processing equipments, and lack of adequate control over the polymerization process. The difficulty may result from any one, or combination of, these problem areas. Dow Corning has indicated that they are fully committed to a program to investigate and resolve these problems. They forecast a much improved fluorosilicone sealant by the end of the year, indicating that this sealant will have a maximum service temperature exceeding that of the best fluorosilicone sealants now available by at least 100°F for extended service life. Additionally, it is expected that further improvements will result from compounding changes.

Promising new materials that may be available for the production phase of the B-2707 (and possibly for the prototypes) are General Electric's nitrile silicone, Hooker's triazine, AFML's 100 percent Solids Viton, and 3M's fluoroalkyl ethers, as well as the new versions of the Dow Corning fluorosilicones.

11002. HIGH-STRENGTH STEEL EVALUATION PROGRAM

Forged billets of 4330M, 4340M, H-11, 9Ni-4Co-0.30C, 9Ni-4Co-0.45C, and Maraging (18% Ni) 250 steels are being evaluated. Previous progress reports have described tensile, fracture toughness (K_{Ic}), and saltwater crack-growth (K_{Ii} versus time-to-failure) test results.

Fatigue and saltwater alternate immersion tests are currently in progress. The preliminary fatigue test data is plotted in Fig. 45. Smooth specimens for alternate immersion testing are statically loaded to various stress levels and alternately immersed in saltwater and room temperature air. Susceptibility to stress corrosion is measured in terms of time-to-failure. Table XXIV summarizes the data obtained to date.

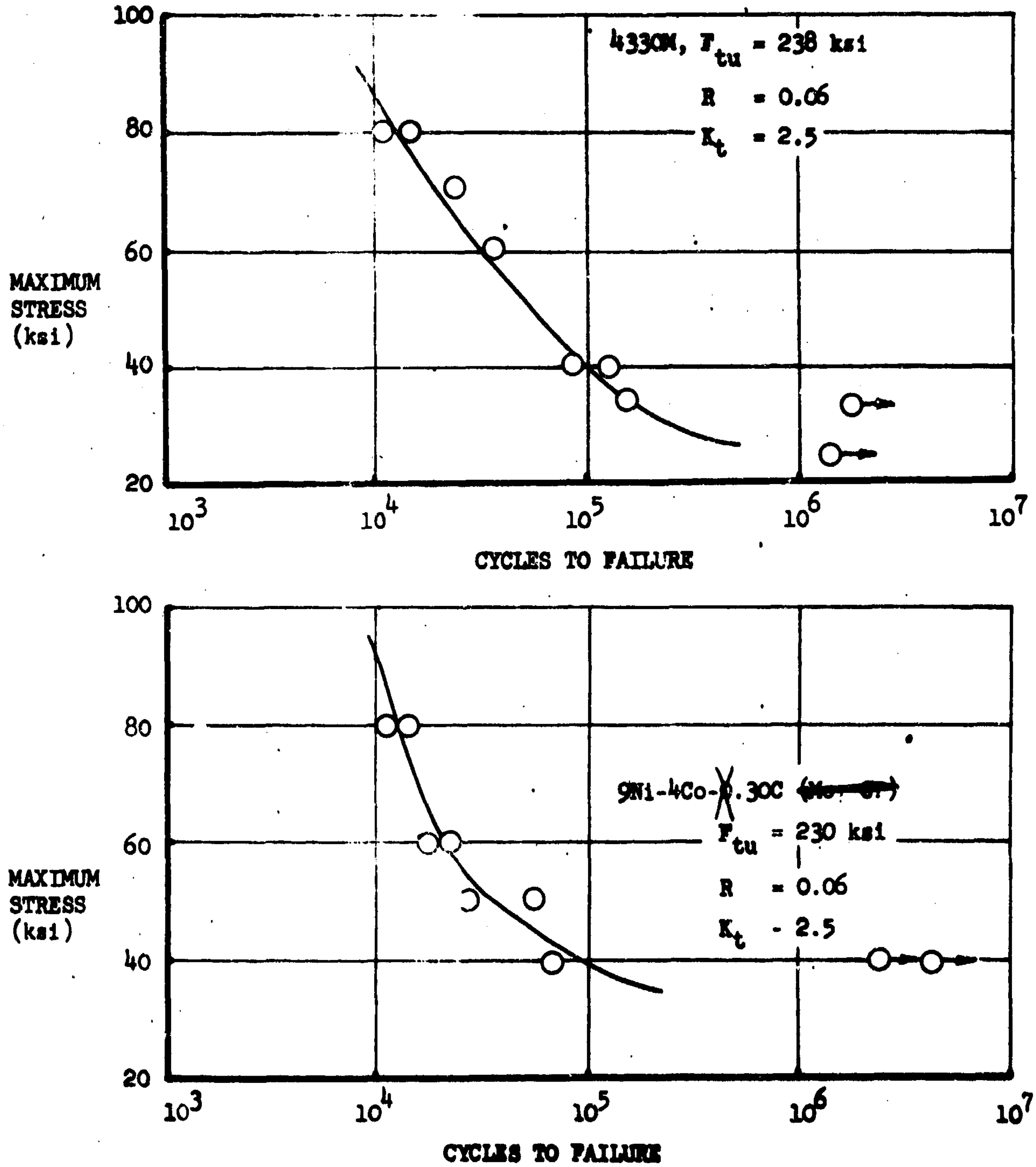


Figure 50. Fatigue Properties of Vacuum-Melted 4330M and 9NI-4CO-.30C, Transverse Grain Direction

Table XXIV. Alternate Immersion Test Results

Specimen Numbers	Alloy	Days to failure*	Stress level (ksi)	YS (ksi)
A92	4330M	NF	157.5	197.7
A93	"	16	"	"
A94	"	15	"	"
A95	"	18	153.0	191.2
A96	"	NF	"	"
A97	"	18	"	"
A98	"	10	158.5	198.0
A99	"	4	"	"
A100	"	4	"	"
D92	4340M	5	186.5	233.2
D93	"	6	"	"
D94	"	5	"	"
D95	"	6	191.5	239.1
D96	"	2	"	"
D97	"	2	"	"
D98	"	2	189.0	236.1
D99	"	2	"	"
D100	"	2	"	"
F95	9-4-0.45 (1)	10	189.5	237.0
F96	"	10	"	"
F97	"	16	"	"
F98	"	2	189.0	236.6
F99	"	16	"	"
F100	"	24	"	"
G95	9-4-0.45 (2)	NF	189.5	220.0
G96	"	NF	"	"
G97	"	NF	"	"
G98	"	NF	"	"
G99	"	NF	"	"
G100	"	NF	"	"
C92	9-4-0.30	NF	161.5	201.7
C93	"	NF	"	"
C94	"	NF	"	"
C95	"	NF	"	"
C96	"	NF	"	"
C97	"	NF	"	"
C98	"	NF	"	"
C99	"	NF	"	"
C100	"	NF	"	"

*NF indicates no failure in 24 days; specimens still in test.

(1) Quench and temper heat treatment

(2) Bainitically heat treated

11002. High-Strength Steel Evaluation Program (continued)

To verify the fracture toughness data determined from notched-bend specimens, several surface-flaw specimens were tested. A comparison of the K_{Ic} data obtained with surface-flaw and notch-bend specimens is shown in Table XXV. Some of the test result variations probably result from different specimen billet locations; these variations are being analyzed further.

To obtain processing experience, three bainitically treated (260-280 ksi) 9Ni-4Co-0.45 landing gear torsion links are being fabricated. Finish machining of these forgings is on schedule.

Diffusion Brazing

Copper diffusion-brazed Ti 6Al-4V lap specimens were subjected to a sodium chloride slurry and exposed at 600°F for 500 and 1000 hr. Room temperature static tensile test results given in Table XXVI show that the static strength properties for the brazed joints are similar to those for the parent metal before and after exposure. Room temperature fatigue test results of brazed-joint and base metal Ti 6Al-4V specimens shown in Fig. 51 indicate that fatigue life for diffusion-brazed joints is slightly less at the higher stress levels, but are equal at lower stress levels.

11003. STRUCTURAL ALLOWABLES

(1) Shear Webs

Testing has been completed on 10 Ti 6Al-4V shear panels similar in design to those of D6-17488-4.

Stiffener-to-web riveting was reduced on this series of tests compared to the amount used on the previous four Ti 8-1-1 riveted panels. Riveting sufficient to develop a shear flow of 40 percent of the web allowable was employed satisfactorily on this group of panels.

All tests were performed in jigs using titanium tee-section chords. The chords were designed to be consistent in strength with the heavier webs tested, thus allowing the web stiffeners to carry the proper diagonal-tension-induced compression loads.

Test versus predicted loads are plotted on Fig. 52 and show good correlation except for the 0.125 webs. In both of these tests, premature jig failures prevented the webs from developing their full strength, as they did when tested in heavier jig structure in an earlier series of tests.

Except as noted above, all failures took place in the basic webs and at stress levels that equal or exceed those proposed for design. Neither the stiffeners nor the fastening to the shear web proved to be critical, thus verifying the design methods employed.

Table XXV. Comparison of Fracture Toughness Test Results for Surface-Flawed and Notched-Bend Specimens

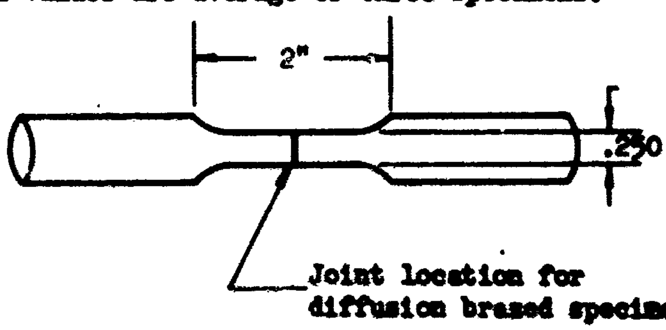
Alloy	Fracture toughness, K_{IC} (ksi $\sqrt{in}$)	
	Surface-flawed specimens	Notched-bend specimens
4330M	83.3 90.8	81.4 88.4
H-11	38.6 44.2	36.9 54.1
9Ni-4Co-0.30C	118.2 119.5	121.5 122.3
4340M	54.8 51.5	68.8 66.4
Maraging 250	107.6 105.6	99.8 98.0
*9Ni-4Co-0.45C	81.6 --	76.9 89.4

*Bainitically heat treated

Table XXVI. Room Temperature Static Tensile Test Results

Exposure Condition	Base Metal Specimens: Tensile stress (ksi)	Base Metal Specimens: 0.2% Offset yield stress (ksi)	Cu Diffusion Brazed Specimens: Tensile stress (ksi)	Cu Diffusion Brazed Specimens: 0.2% Offset yield stress (ksi)
1900°F, 60 Min	137	117	139	121
1900°F, 60 Min 600°F, 500 Hr (NaCl)	145	126	145	126
1900°F, 60 Min 600°F, 1000 Hr (NaCl)	147	127	149	128

NOTE: All values are average of three specimens.



The first sine-wave corrugated web shear panels have been received and equipment is being designed for their testing.

(2) Compression Panel Testing

Testing has been completed on the remaining 19 compression panels and 19 crushing panels. Crushing tests have also been performed on 78 stiffener sections of the type used on the compression panels. Testing of coupons to obtain basic material properties will be completed early in August.

A summary of test results are shown in Table XXVII. Predicted allowables, which were based on Johnson-Euler formula and standard properties, are shown for comparison. End fixity has been assumed as 3.5, except in those cases where deflection measurements indicate considerably less. For those panels, an end fixity of 2.0 is used. Reasonable correlation was obtained between test and predicted values. Predicted panel loads are approximately 10 percent greater than test values. Panel eccentricities, alignment, and end flatness affect developed test end fixity. Small variations in these factors can produce changes in test end fixity and materially affect test results.

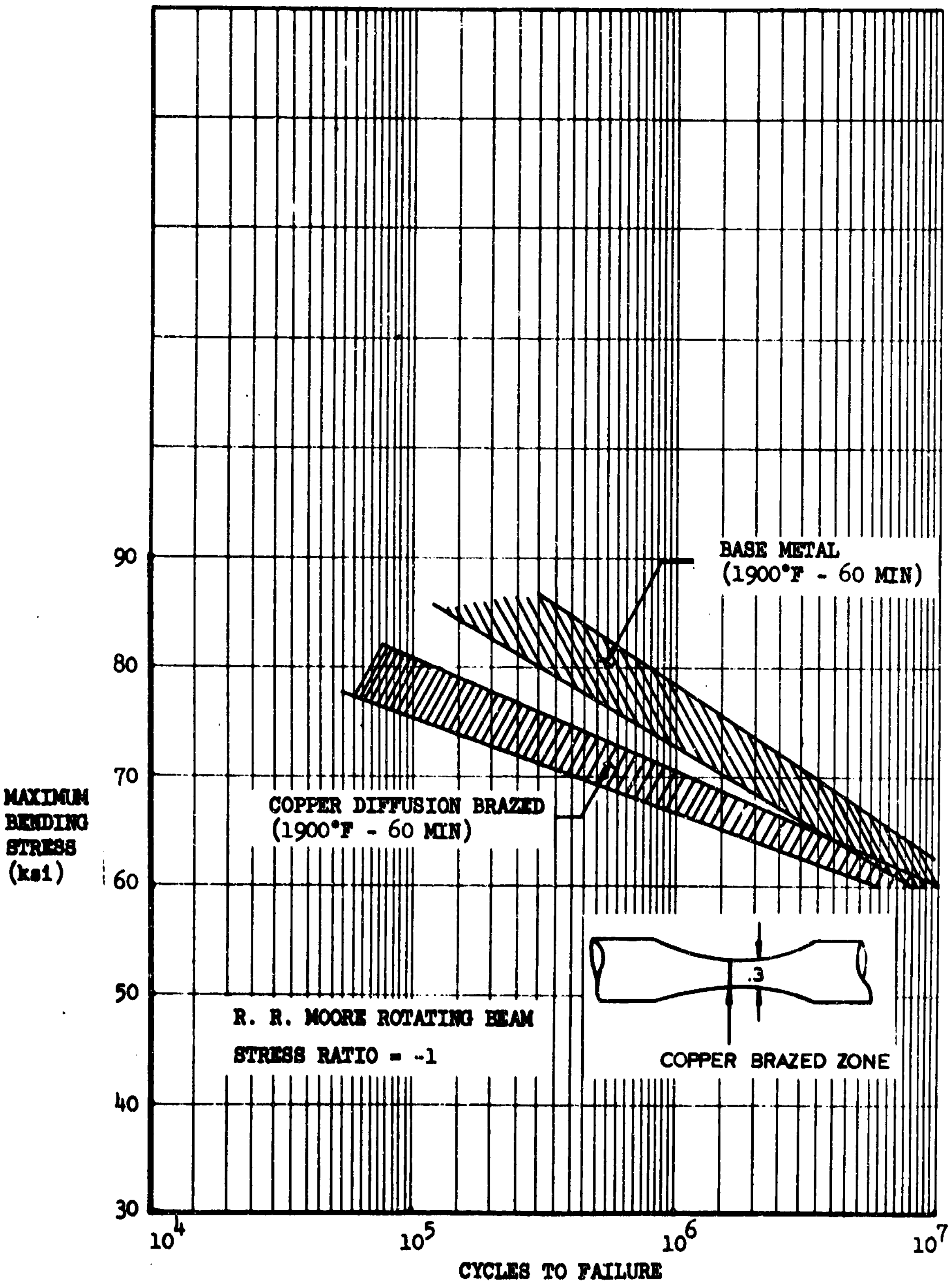


Figure 51. Fatigue Test Results, Copper–Diffusion–Brazed and Base Metal Titanium 6Al–4V

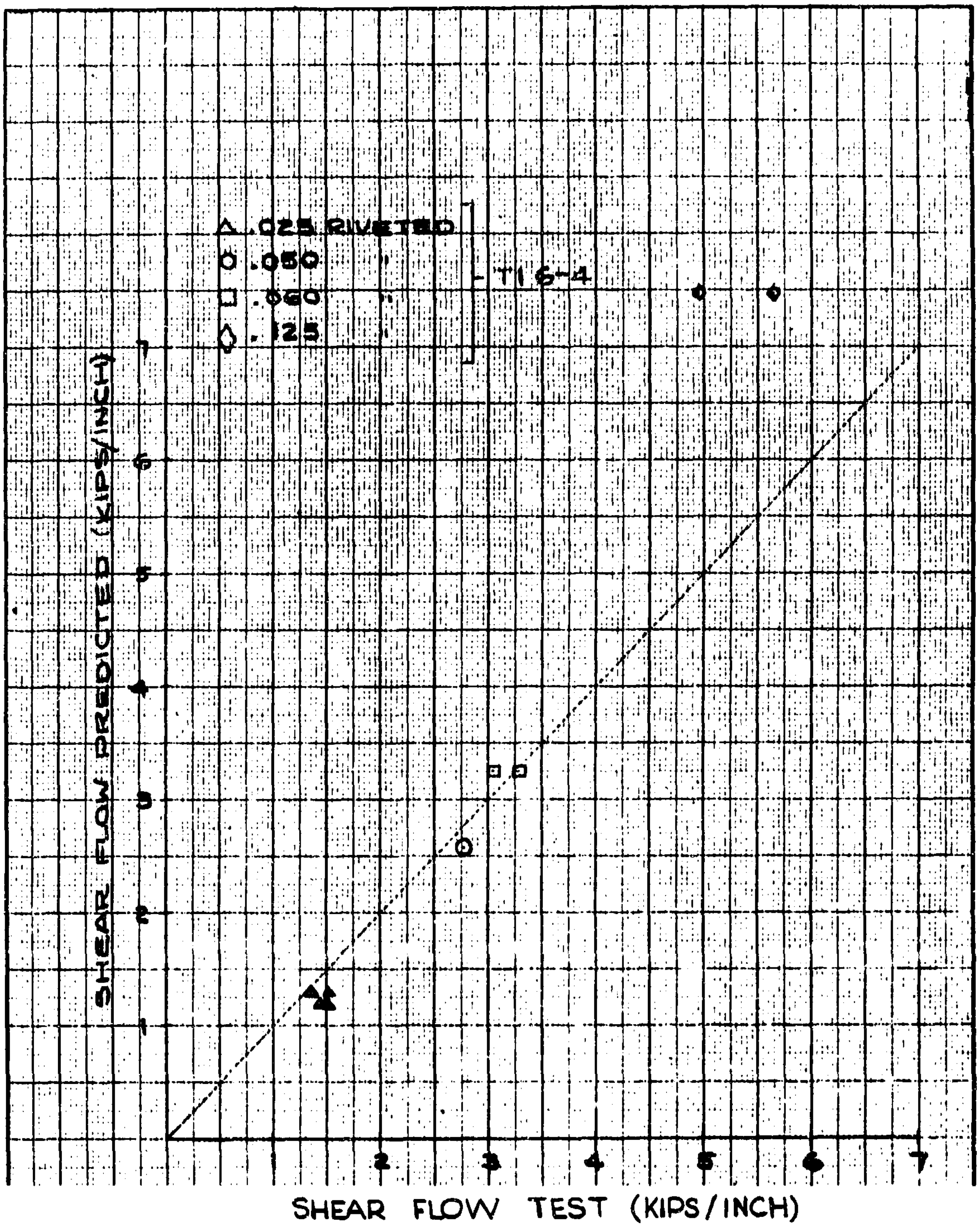


Figure 52. Shear Wet Test Results Actual Versus Predicted

Table XXVII. Compression Panel Comparison Test Versus Calculated Results Riveted Panels

TEST PANEL	LENGTH (in.)	TEMPERATURE °F	TEST LOAD (kips)	PREDICTED LOAD (kips) 1▷
V	46.5	70	498	519 ▷
	73.5	70	319	392
	46.5	500	447	475
	73.5	500	300	333
	46.5	500-200 2▷	454	495
	46.5	200-500 3▷	402	416 ▷
VI	52.5	70	244	286
	70.0	70	157.5	164
	52.5	500	212	229
	70.0	500	135	143
	52.5	500-200 2▷	212	240
VII	28.0	70	80.0	84.5 ▷
	39.0	70	63.0	62.9 ▷
	28.0	500	62.9	69.8 ▷
	39.0	500	51.0	54.9 ▷
	28.0	500-200 3▷	58.5	65.7 ▷
VIII	30.0	70	36.0	34.7
	37.0	70	35.1	34.9
	30.0	500	32.9	29.6
	37.0	500	30.5	28.2
	30.0	500-200 3▷	32.0	26.9
	30.0	200-500 3▷	32.4	26.2
IX	37.0	70	49.9	53.8
	37.0	500	42.0	44.8

▷ Using C = 2 based on test deflection data

1▷ Based on standard material properties

2▷ Skin temperature 500°F; outstanding flange temperature 200°F

3▷ Skin temperature 200°F; outstanding flange temperature 500°F

11003. Structural Allowables (continued)

In the heavier sections, panel failure resulted from loss of stability, due to premature stiffener roll. Unlike the rib flange in the airplane, the simulated rib flange installed on the panel is free to translate. Changes in end fixity produce a different effective length than that of the simulated rib spacing and combined with free translation of the rib member allow premature stiffener rolling. In actual application, the outstanding flanges of the stiffeners are restrained from translation by the ribs and thus prevent stiffener roll. Therefore, the use of the Johnson-Euler prediction methods should give accurate indications of panel allowable loads in actual applications.

Measurements of lateral deflection were made at several points along the height of the panels. The deflected panel shapes described by these measurements show that in some cases the end fixity of the test specimen approaches a value of 2.0, instead of the 3.5 assumed value. In those cases the lower value was used in calculating the predicted loads and these are so noted in Table XXV. Changes of effective spacing for the simulated rib members were not included for lower end fixity calculations. Stiffeners were riveted to the skin panels in this series of tests resulting in much less initial eccentricity in the panels than in the spotweld specimens; no correction factor for eccentricity is included in the analysis of these panels.

Strain gage measurements were taken on the skin panels of all column specimens tested at room temperature to determine accurately the stress at which skin buckling takes place. The information will be used to verify the skin buckling coefficients used in current design.

(3) Honeycomb Allowable Testing

Testing has been accomplished on honeycomb sandwich specimens after exposure up to 3,800 hours in a 450°F oven. The test specimens were cut from large structural panels typical of the airplane usage and were subjected to compression to show the effects of the exposure on the honeycomb allowables. Three titanium alloys were sampled and all three showed only a negligible loss in allowable stress. The data are presented in Fig. 53 and a photo of a typical specimen mounted in the test jig is shown in Fig. 54.

11004. STRUCTURAL DESIGN CRITERIA

(1) Surface Waviness

The final stage of testing the honeycomb panel mounted on the thermal box was completed on schedule in June. The panel had been reinforced by straps bolted against the tapered edges of the honeycomb panel at the ribs and spars. The size and thickness of the straps was chosen to give the same stiffness as an increase in skin gage in the tapered areas.

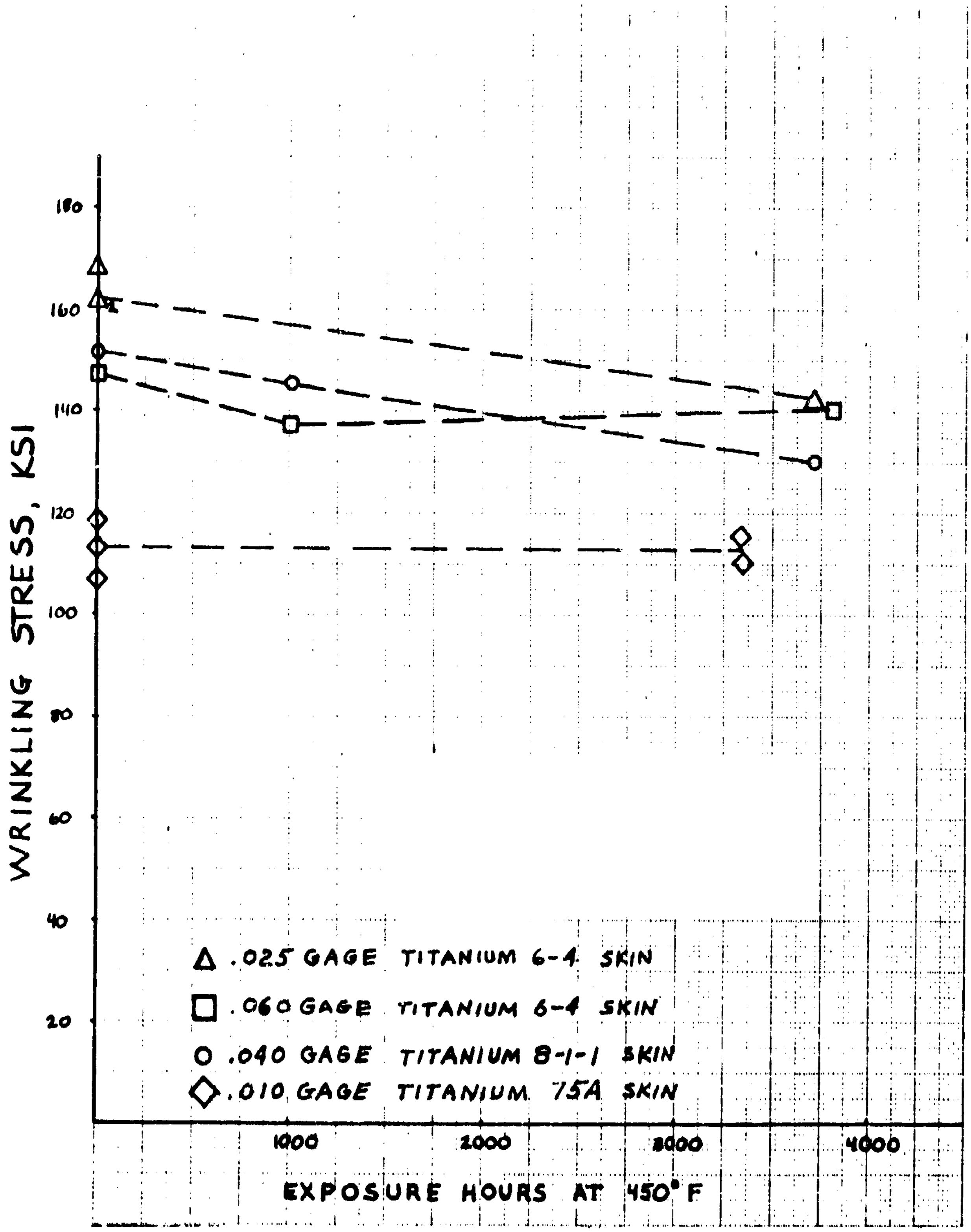


Figure 53. Sandwich-Face Wrinkling Stress Versus 450° F Exposure Time

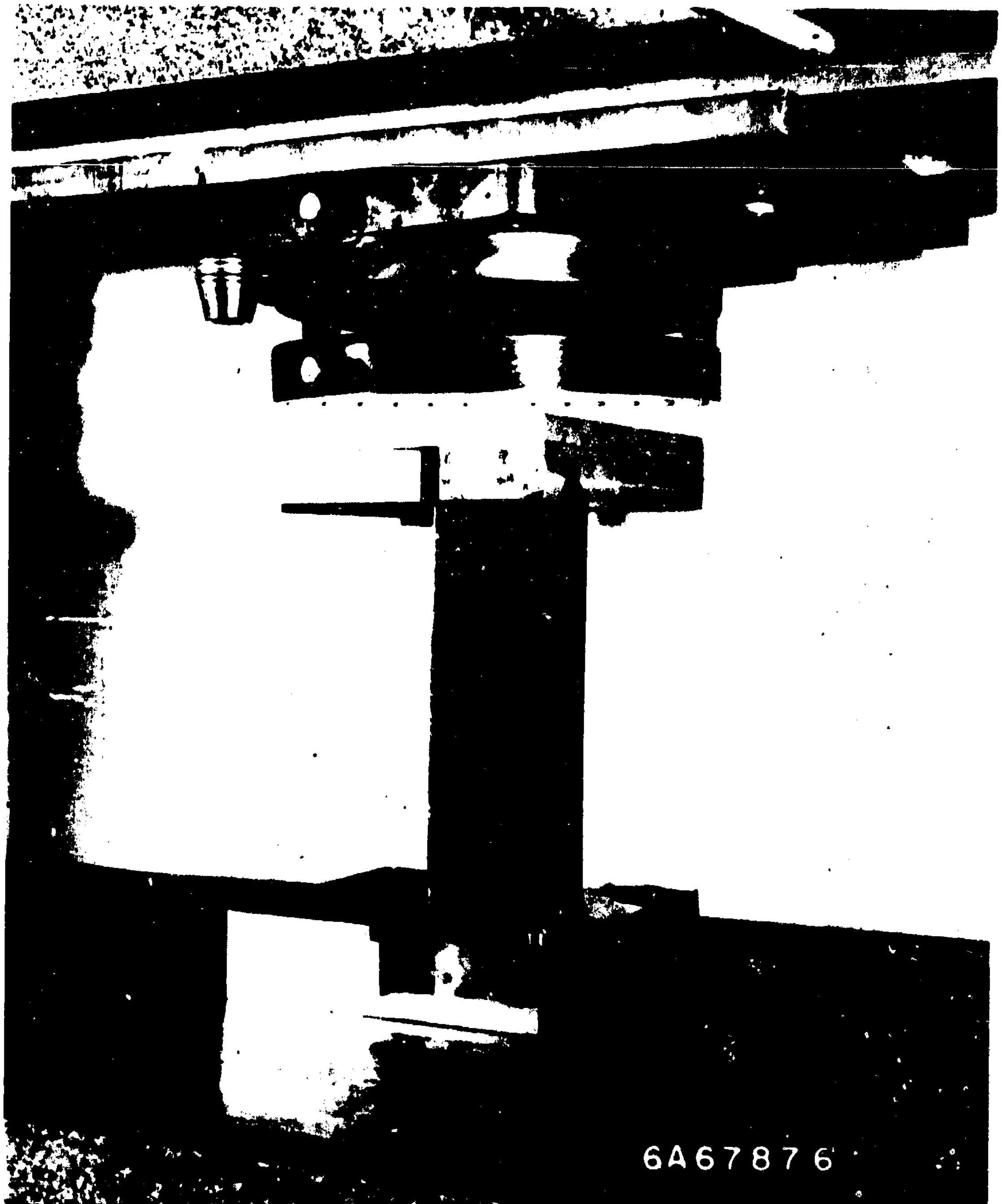


Figure 54. Honeycomb Sandwich Test Specimen

11004. Structural Design Criteria (continued)

The panel was subjected to tests involving side load, end load, internal pressure and heat applied separately, and several combinations of these tests. Surface deflections, stresses, and temperatures were recorded continuously. Normal methods of calculating panel deflection were found to be accurate for the cases of thermal gradients and internal pressures and conservative where these cases were combined with side and end loads except when local buckling developed. Thermal deflections were prevented at high longitudinal loads when the loads preceded the thermal gradient but not when the thermal gradient preceded the load.

The maximum stress level developed in the center of the panel prior to local buckling at the edge under side load was 43,000 psi, a 33-percent improvement over the previous side load test without the external reinforcement. The local buckle was attributed to lack of flexural stiffness at the edge and lack of torsional stiffness in the spar chord. The panel did not fail. The maximum stress level developed in the center of the panel prior to local buckling and failure at one rib station under end load only was 69,000 psi, a 67-percent improvement over the previous test without the external reinforcement. The failure was attributed to lack of torsional stiffness in the one rib chord, since no rotation was observed in the other rib chords.

Figure 55 shows the panel being subjected to longitudinal and lateral loads prior to external reinforcement.

Figure 56 shows the panel with the external reinforcements that simulated the effect of additional stiffness in the outer skin of the panel.

Figure 57 shows the effect of heat and end load on panel waviness.

The empennage test structure is currently being fabricated. A document (D6A10235-1) containing a stress analysis of the structure was released in June. The honeycomb panels on this structure were designed to exhibit general buckling in place of the local buckling experienced in the thermal box.

(2) Fail-Safe Tests

Crack growth testing has been initiated on the latest fuselage pressure section test panel (Ref. D6-18110-4, page 130). The 6-inch initial starter crack was centered in an 0.032-gage Ti 6-4 Condition I skin panel bordered by stringers and frames. The crack was extended by pressure cycling at 12 psig to the dual tear straps at the frame stations. The 0.040 by 0.87 Ti 6-4 Condition I dual tear straps are attached to the skin with countersunk A286 corrosion-resistant steel rivets. Crack growth was greatly retarded, as the crack tip extended

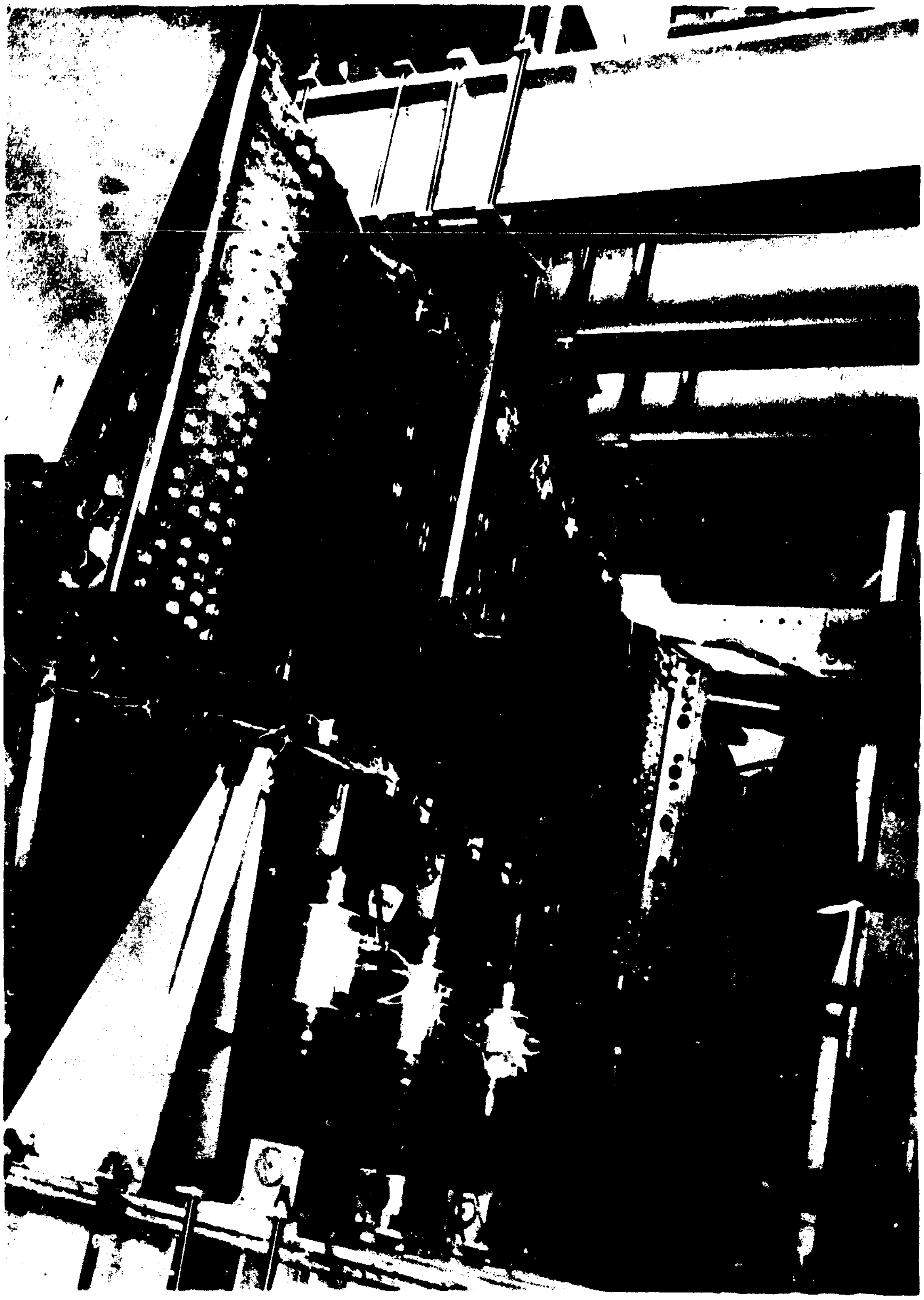


Figure 55. Honeycomb Panel – Longitudinal and Lateral Loading, No External Reinforcement

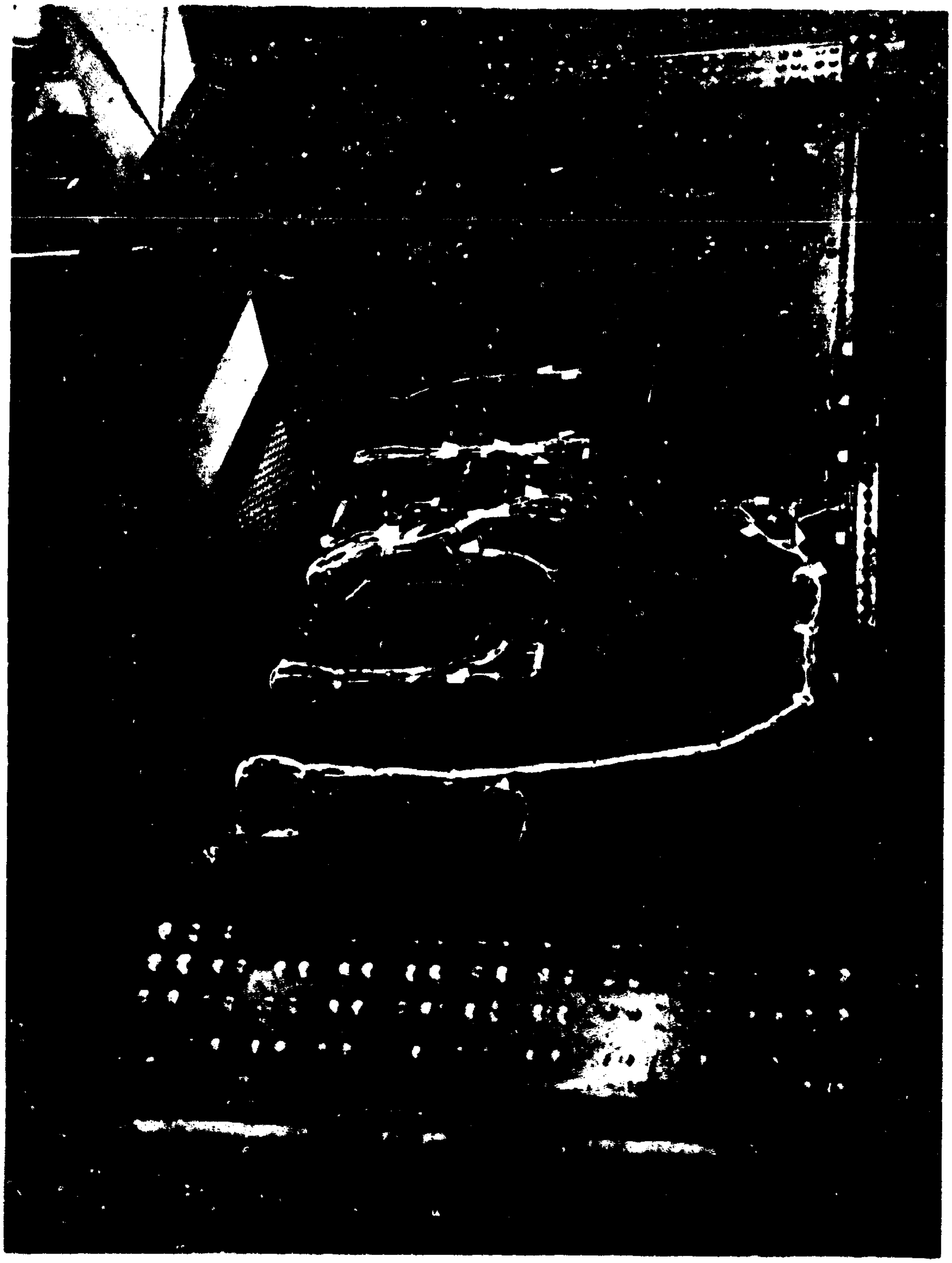


Figure 56. Honeycomb Panel – External Reinforcement

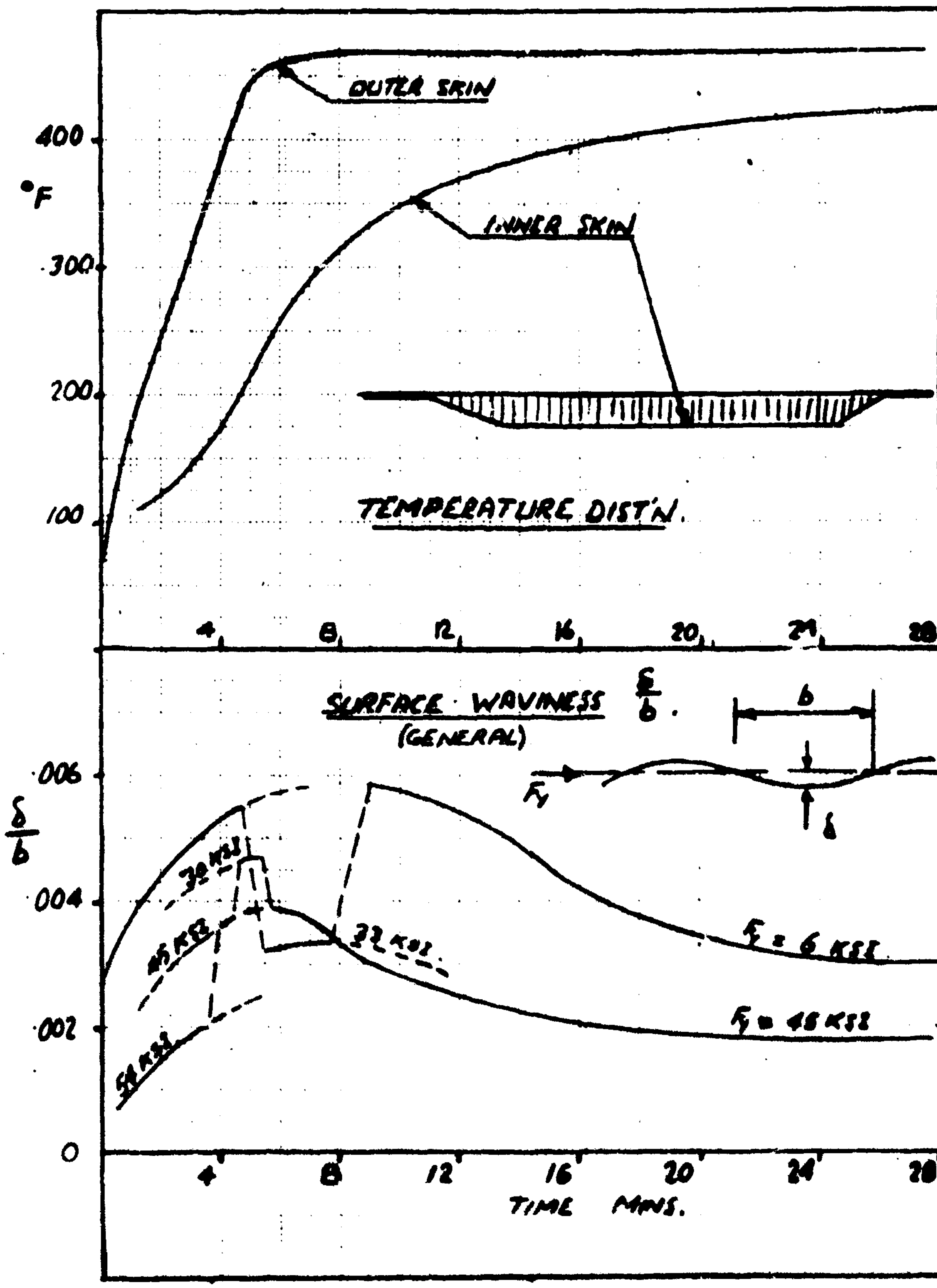


Figure 57. Test Results, Honeycomb Panel.

beyond the centerline of rivets at the first tear strap. The pressure was maintained at 12 psig for 10 minutes with no significant growth and the crack growth was considered arrested. The crack growth history of the test is shown in Fig. 58.

(3) Fatigue Tests

Fatigue testing of baseline specimens is continuing. This type of specimen is used extensively for evaluation of material, fastener, and temperature effects on fatigue life. The configuration is shown on page 127 of the January 1966 progress report (D6-18110-3). Figure 59 shows recent test results for Ti 8-1-1 specimens fabricated with Taper-Lok fasteners. Test results for Ti 6-4 specimens with Taper-Loks and with A-286 squeezed rivets are shown in Fig. 60. The specimens in these two figures have constant thickness (0.125 sheet) and 1/4-in. diameter fasteners. The effects of material, fastener, and pretest exposure is in work to complete these programs. Variations in sheet thicknesses and fastener diameters are also being evaluated. Test results for Ti 8-1-1 specimens with A286 squeezed rivets are presented in Fig. 61. The overall program includes thicknesses from 0.040 to 0.250 and fastener diameters from 1/8 in. to 5/16 in.

11005. STRUCTURAL LOADS AND TEMPERATURES

(1) Thermal Analysis

A thermal analysis has been conducted on the wing-pivot structure, corresponding to the new configuration. Table XXVIII presents results in terms of maximum pivot-bearing temperatures and pivot-structure temperatures attained during various flight profiles. The temperatures at the time of landing are, in all cases, approximately the same as these maximums. Relative to the past design (Ref. Phase II-A, Report D6-8680-6) this present analysis shows that the new configuration is improved in terms of lowered bearing temperatures and, therefore, better accommodates post-flight maintenance.

(2) Speed-Altitude Diagram

Structural design speed placards for the B-2707 airplane have been established. Speeds for the subsonic low-sweep configurations are shown in Fig. 62. The wing-aft configuration design placards are shown in Fig. 63. These speeds represent an optimization of airplane performance and structural disciplines.

(3) Dynamic Loads

Ride Comfort

A preliminary estimate of B-2707 acceleration levels in turbulent air relative to the B-70, B-58, and 707 has been completed. Figure 64 essentially overlays the B-2707 and 707 center of gravity

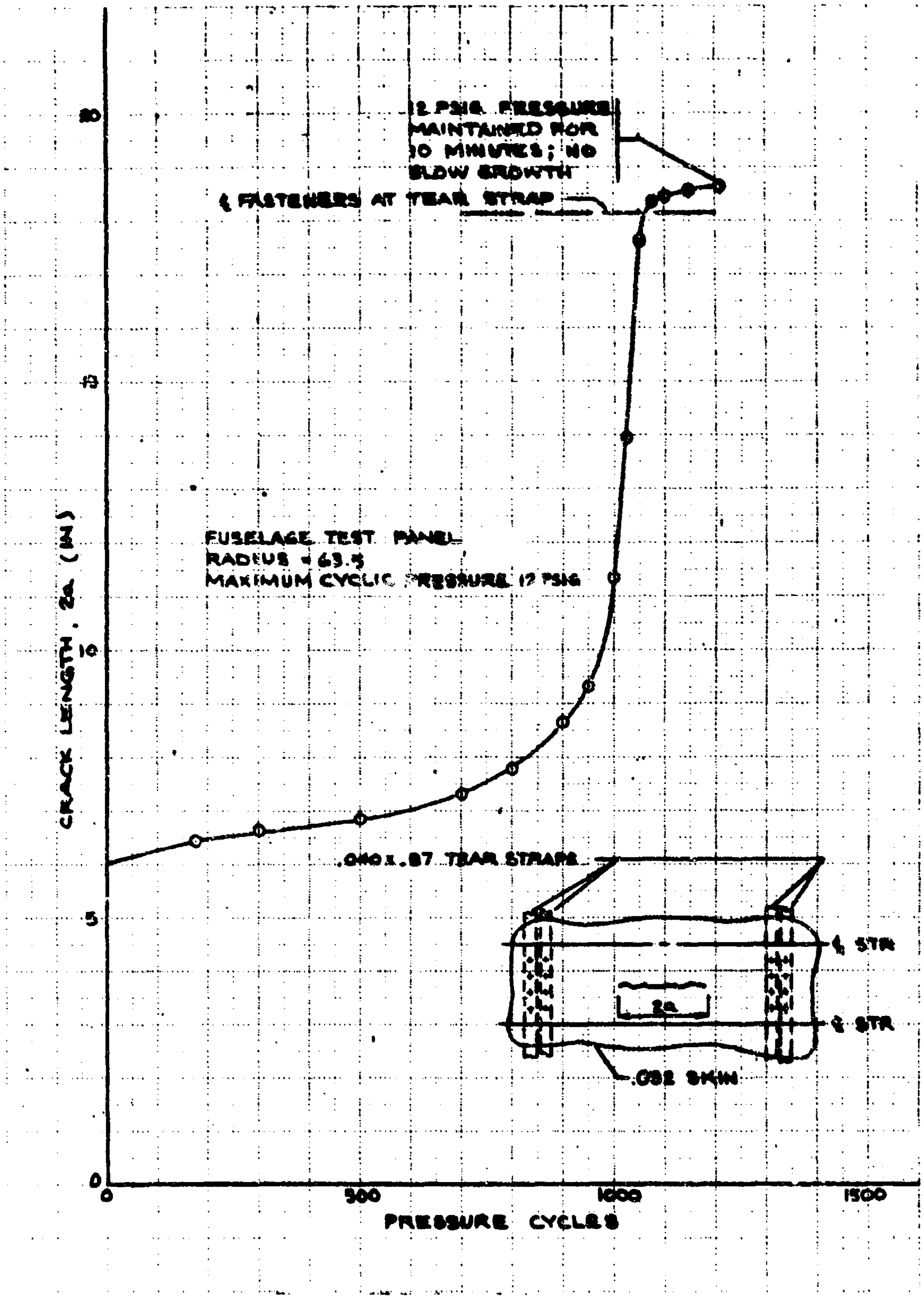


Figure 58. Crack Growth History

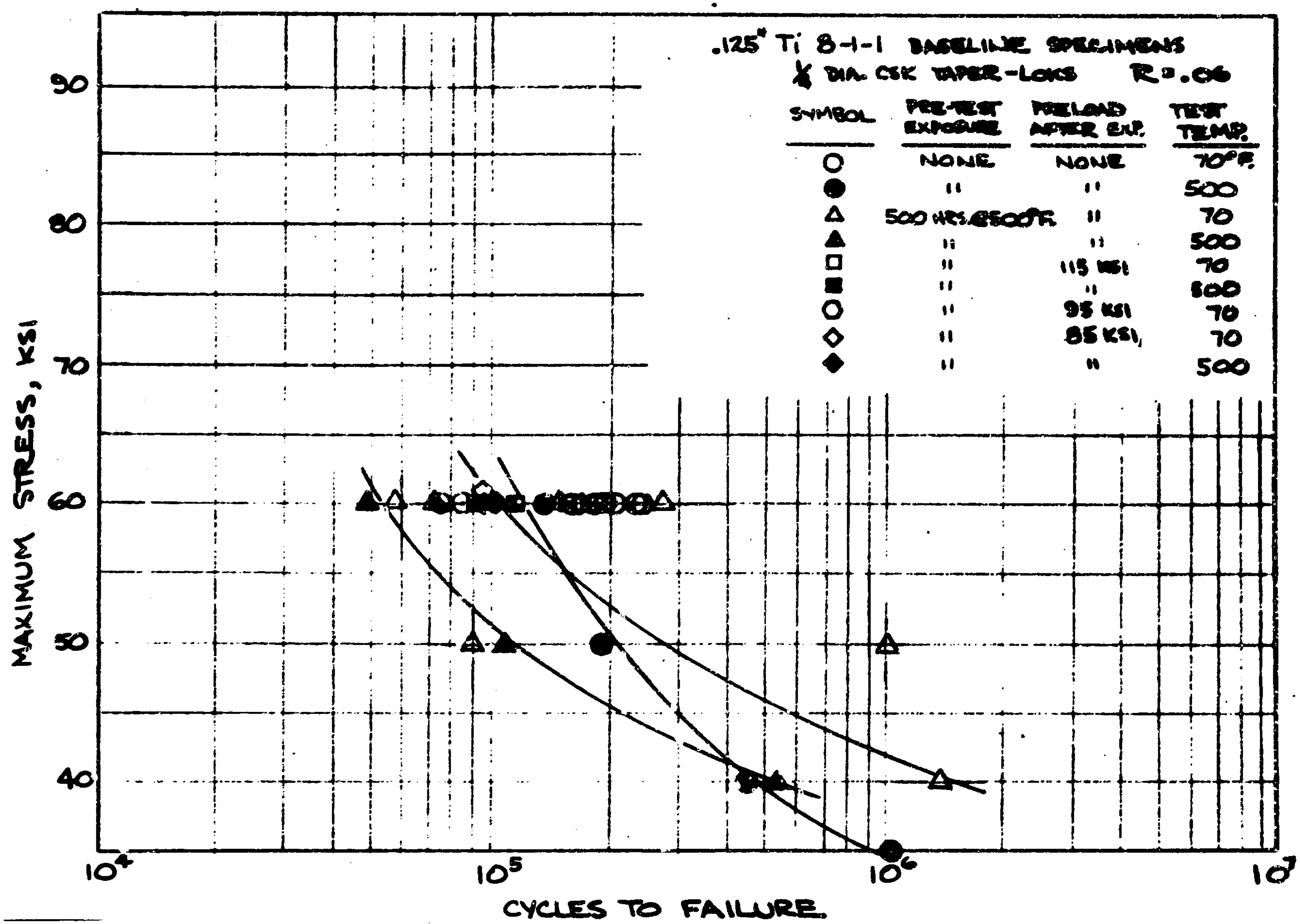


Figure 59. Fatigue Test Results for Ti 8-1-1 Taper-Lok Specimens

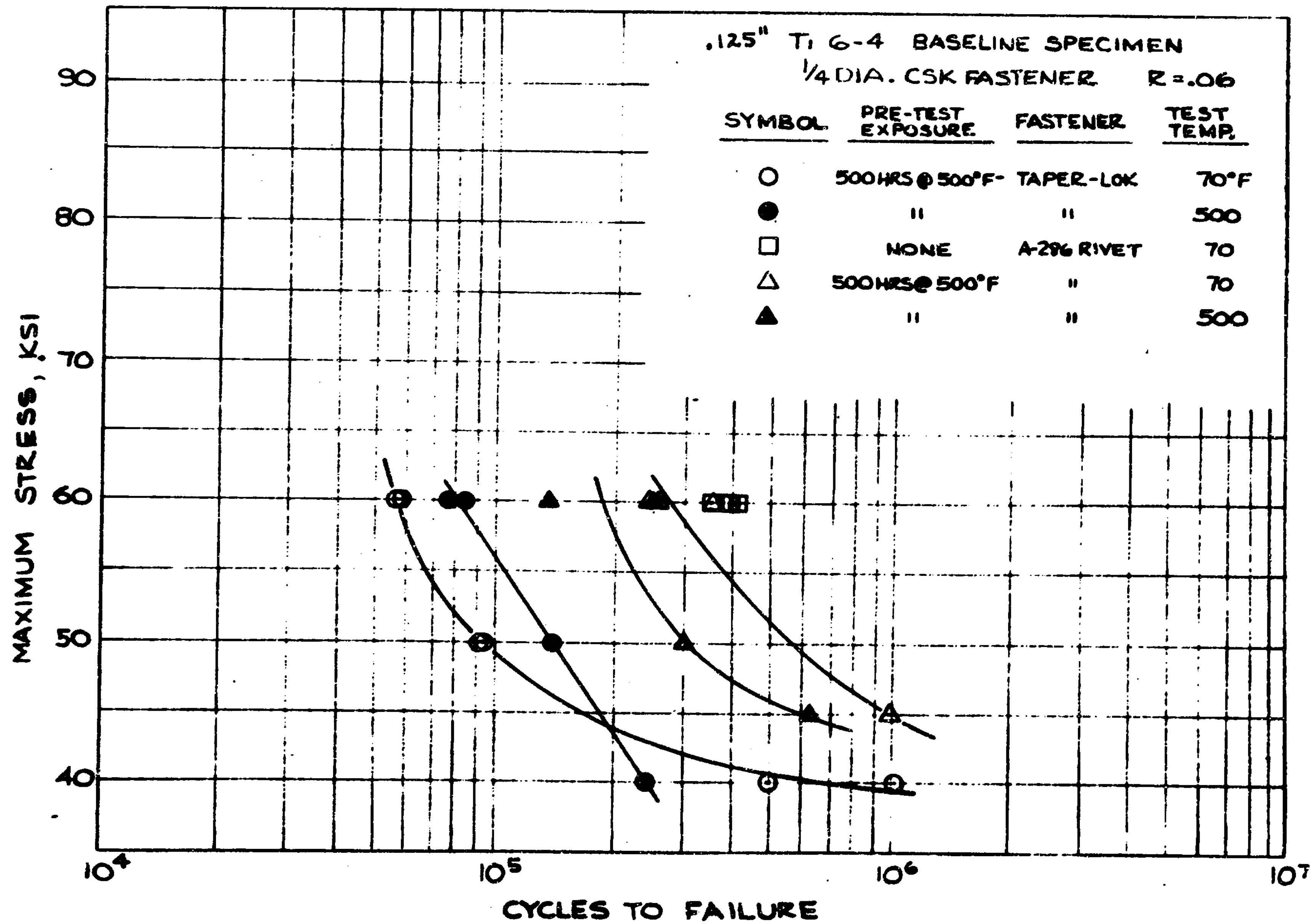


Figure 60. Fatigue Test Results for Ti 6–4 Specimens

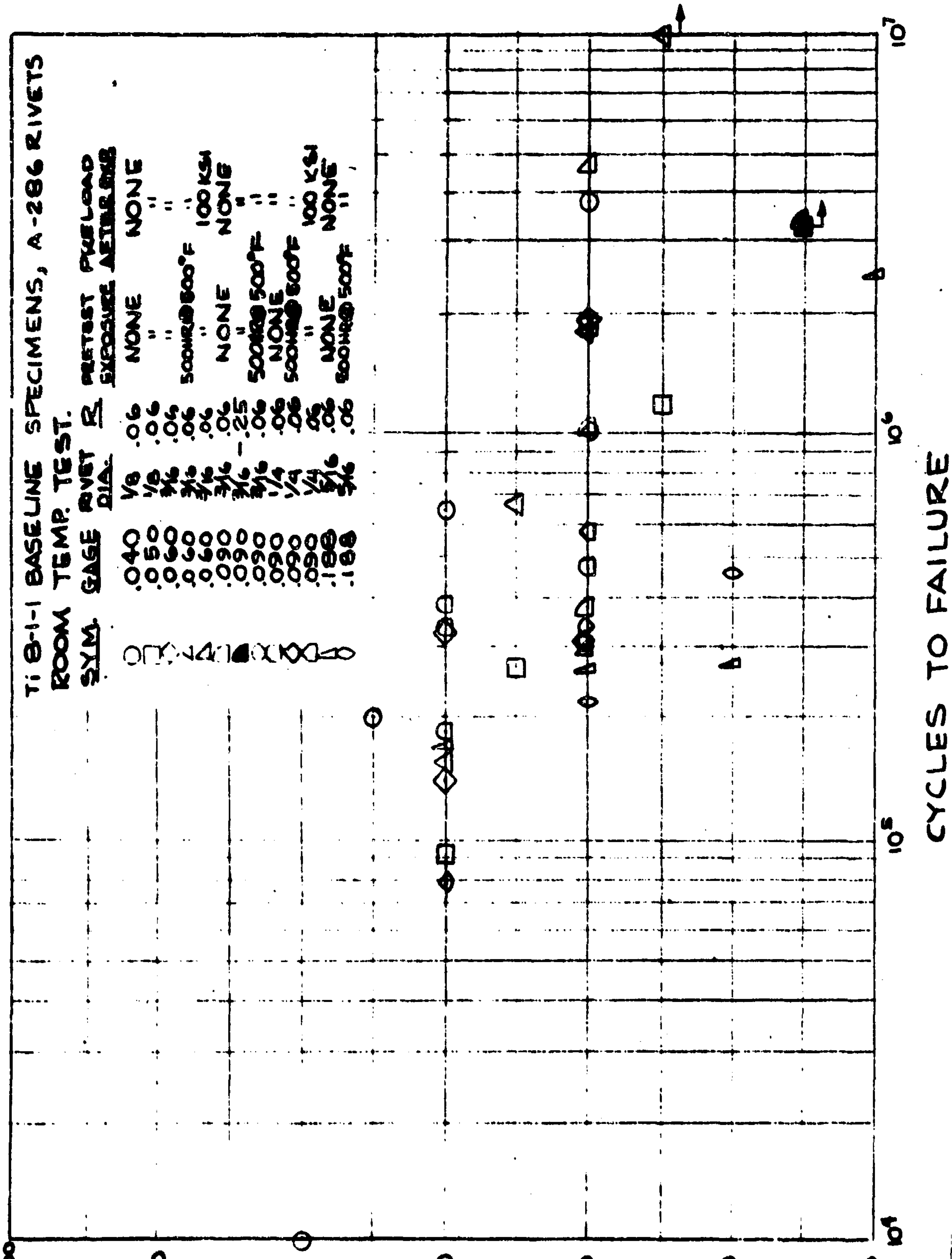


Figure 61. Fatigue Test Results for Ti 8-1-1 Riveted Specimens

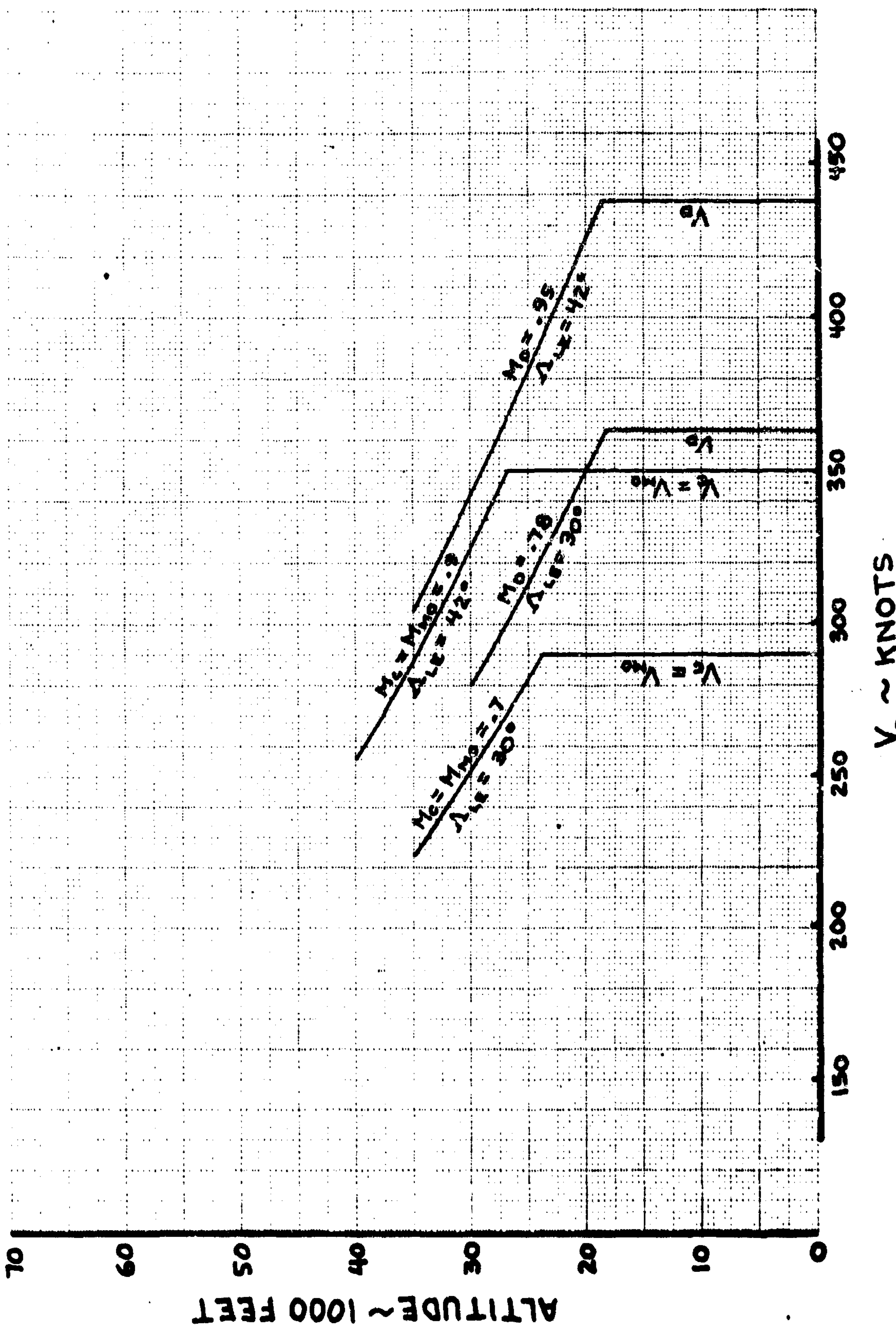


Figure 62. Design Speed–Altitude Envelope, Low – Sweep Range

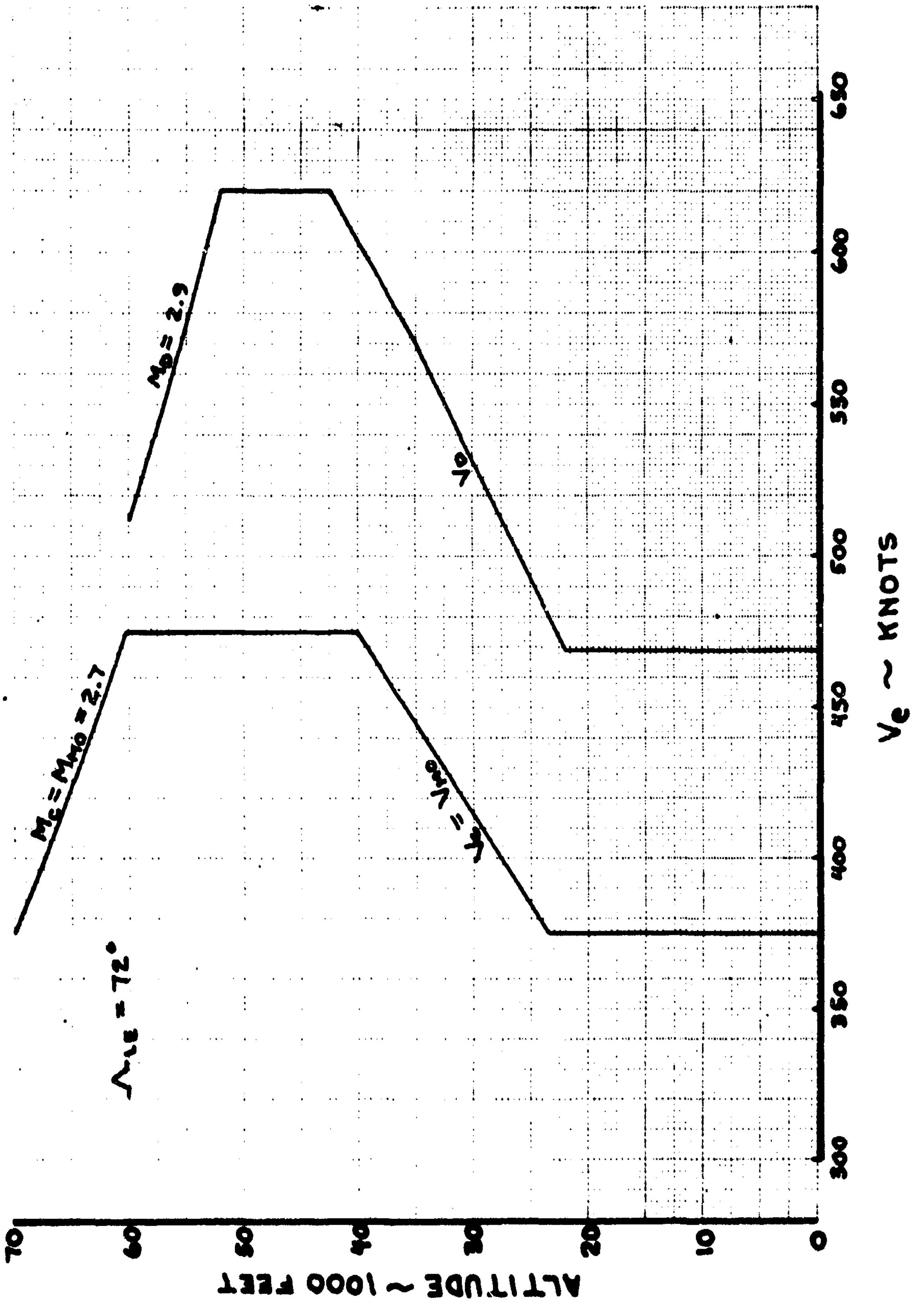


Figure 63. Design Speed – Altitude Envelope, 72 Degree Sweep

D6-18110-6

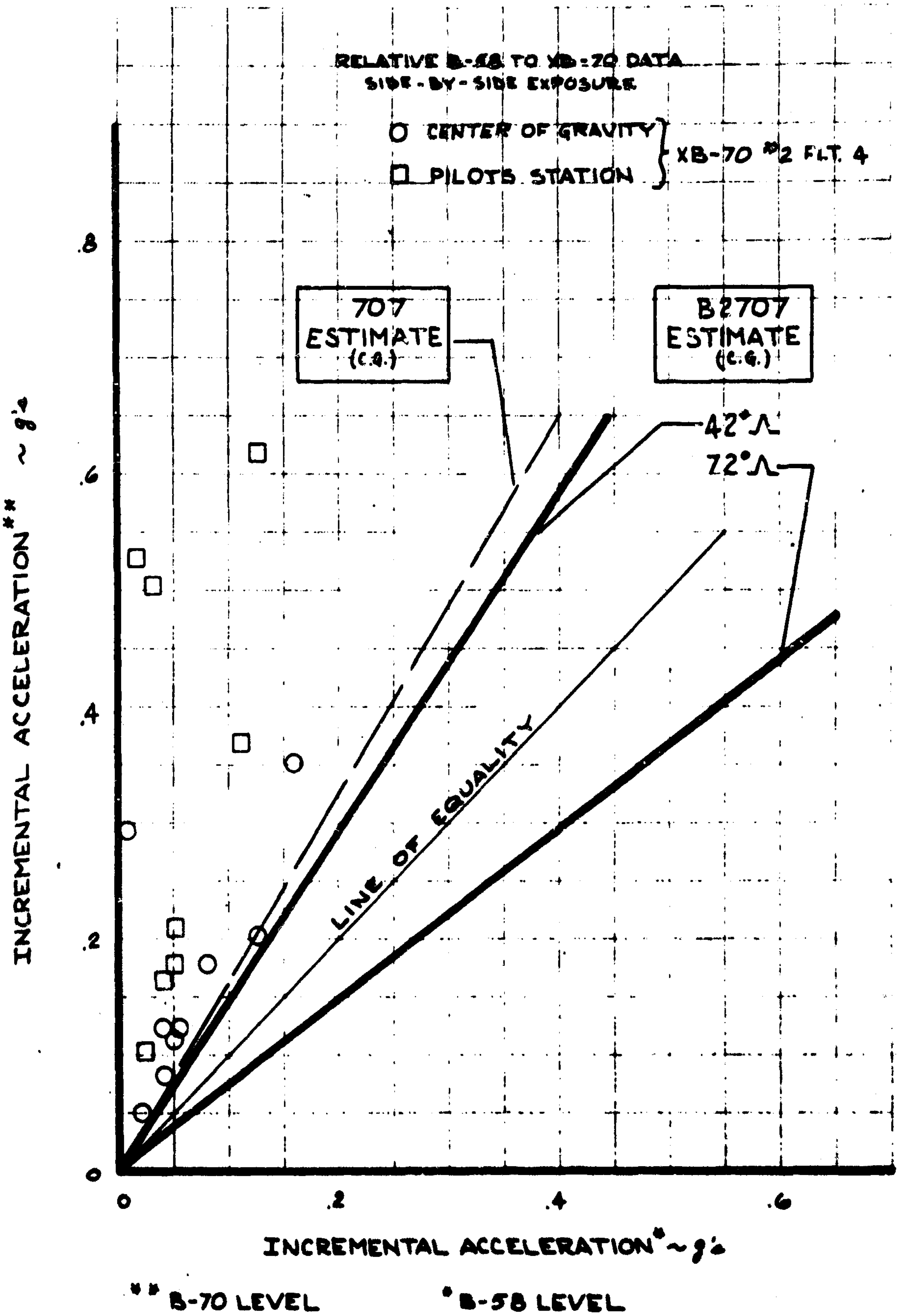


Figure 64. Relative Response to Turbulence of B-2707

Table XXVIII. Flight Profile Test Results

Flight Conditions	Maximum Temperatures (°F) Bearing	Pivot Structure
1) Standard Day, 3,500 NMI Flight	75	111
2) Standard Day, Three 3,500 NMI Flights with 30 minutes ground time between flights	106	159
3) Hot Day, 3,500 NMI Flight	133	163
4) Hot Day, Three 3,500 NMI Flights with 30 minutes ground time between flights	157	200

estimates on a background of B-70/B-58 data gathered by flying both airplanes through turbulence together. As can be seen, the comparative flight data support the rough-ride experience reported for the B-70. By comparison, the B-2707 estimates are shown to be more favorable for the 72-degree wing-sweep position than for even the smooth-riding B-58. In the 42-degree wing-sweep position, the B-2707 estimate is shown to approach (but remain less than) the 707 estimate, although exceeding the B-58 ride level. Partial confirmation of the foregoing comparisons is offered by Fig. 65, which shows the product of lift curve slope (C_{L_a}) and reference area (S_{REF}) for the B-2707 and a typical delta SST configuration. This comparison illustrates the greater advantage of increased wing sweep for a given airspeed.

The unexpectedly high acceleration level shown by B-70 data is believed to reflect special canard effects, rather than any effect of increased airframe flexibility. Possible effects of the canard are:

- Direct structural excitation
- Aerodynamic damping
- Gust-induced flow separation
- Vortex shedding

While all these effects may be present, aerodynamic effectivity of the canard surface allows for a very significant level of structural excitation that can easily feed forward to the pilot's compartment as well as back to the airplane center of gravity. A full analysis of these effects will undoubtedly come out of the B-70 program as presently planned. In the meantime, the airframe flexibility results

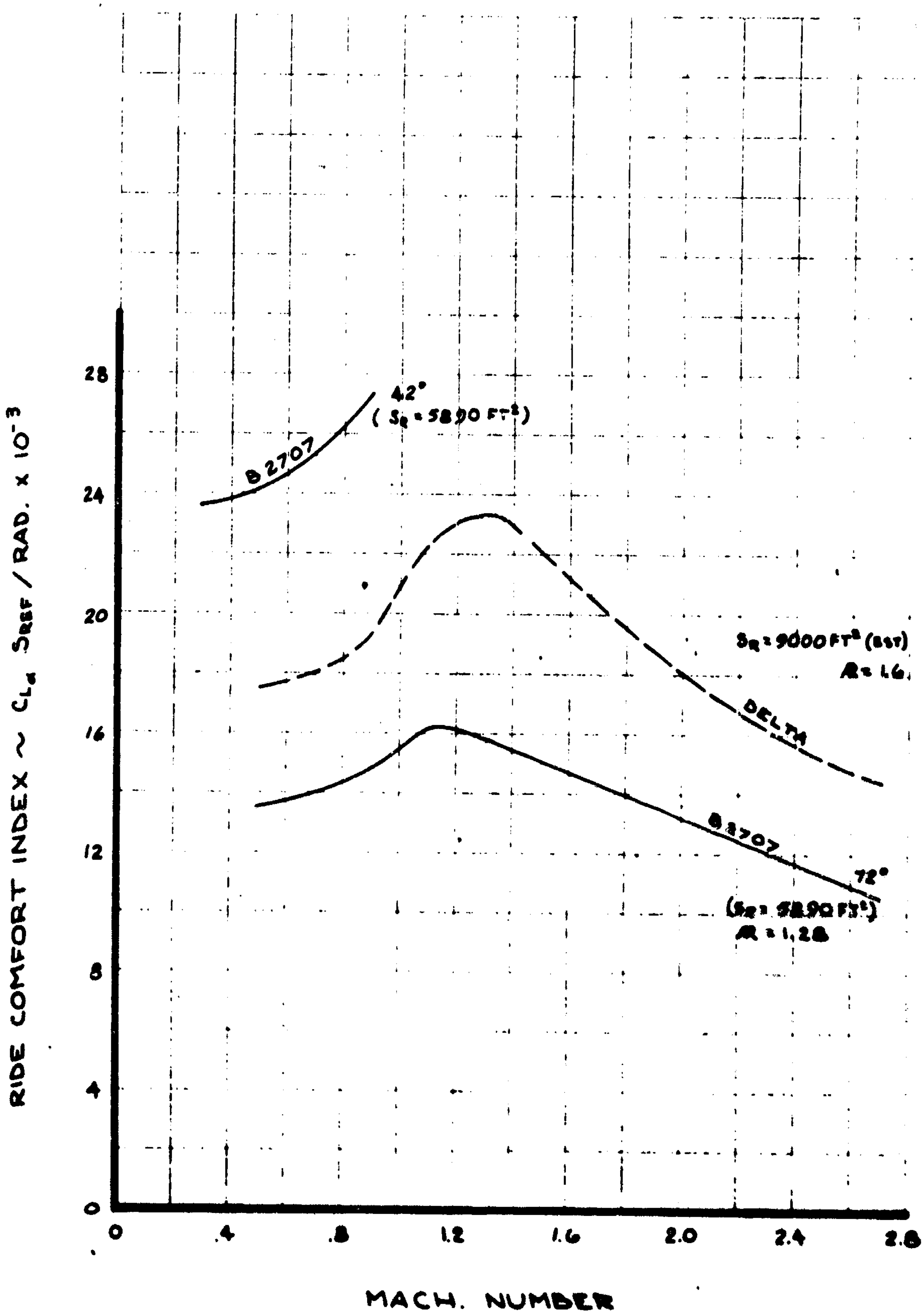


Figure 65. Relative Ride Qualities of B-2707 and Typical Delta Configuration

presented in the May 1966 and January 1965 reports continue to help provide a high degree of assurance that the relatively greater SST body flexibility will introduce no adverse effects on either acceleration environment or subjective response.

11006. FLUTTER

A supersonic flutter test of 0.036-scale cantilevered vertical fins representative of B-2707 configurations was completed in the Boeing Supersonic Wind Tunnel July 20, 1966. Several fins with 50-degree leading-edge sweep and one with 60-degree leading-edge sweep were tested. The 50-degree sweep fins were tested at stiffness increments of 50 percent, 75 percent, and 100 percent of the nominal stiffness and at several increments of mass ratio. The 60-degree sweep fin was tested to evaluate geometry effects on flutter characteristics. A planform comparison of the two fin test specimens is shown in Fig. 66. Test results, obtained over a range of Mach numbers and dynamic pressures shown in Fig. 67, indicate no classical flutter, although some model damage was experienced during lightly damped oscillations. Final data are being prepared.

Vibration testing of a 0.05-scale subsonic model is being conducted in preparation for flutter test in the Convair-San Diego Low-Speed Wind Tunnel beginning July 30, 1966. The model, shown during laboratory vibration test in Fig. 68, is an all-flexible representation of the prototype SST configuration. Variations of structural stiffness, wing-sweep angle, fuel, nacelle chordwise position, and model support will be made during the test.

11008. AIRFRAME STRESS ANALYSIS

A wing-pivot-box structure stress analysis has been completed and is released as Boeing Document D6A10150-1 in compliance with the Detail Work Plan, D6-18139, Item 1100g, 2590. The airframe stress analysis for the prototype airplane is being updated now and will be covered by the analysis presented with the September proposal documentation.

1101. Wing

(a) Tests

(1) The anticipated document release date covering the thermal and load testing of the 12-foot wing box is the end of August.

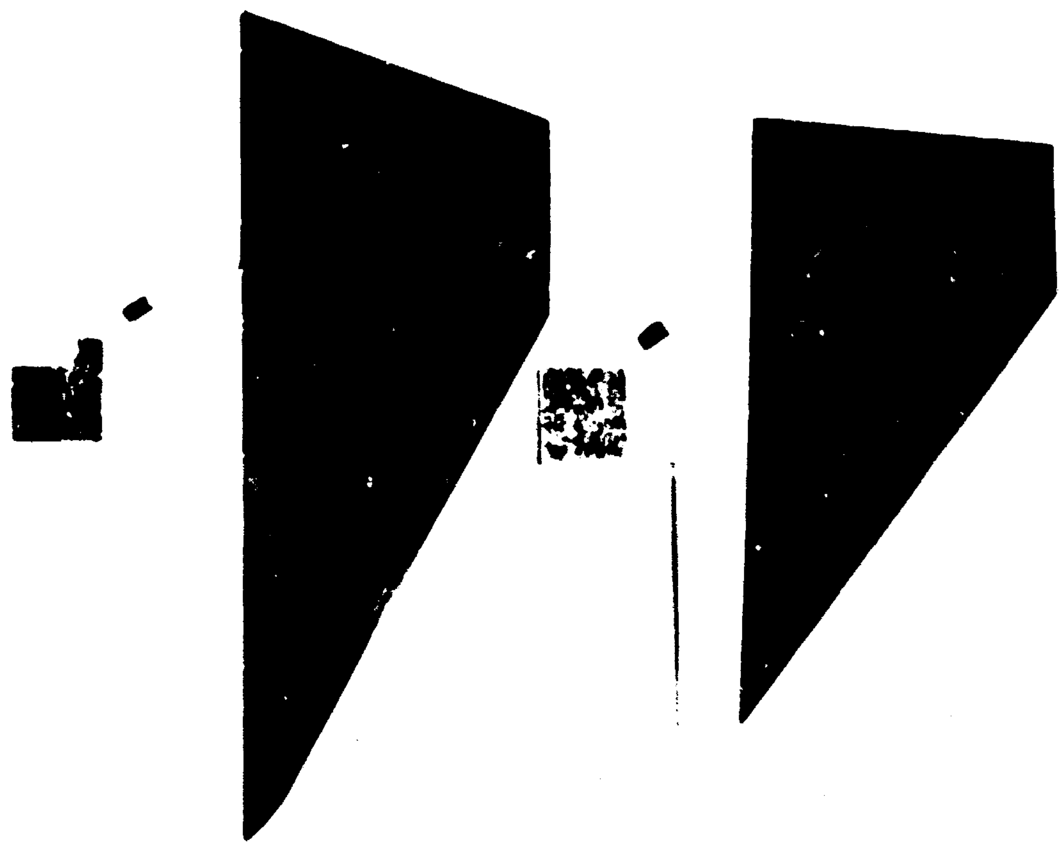


Figure 66. Flutter Test – Fin Planforms

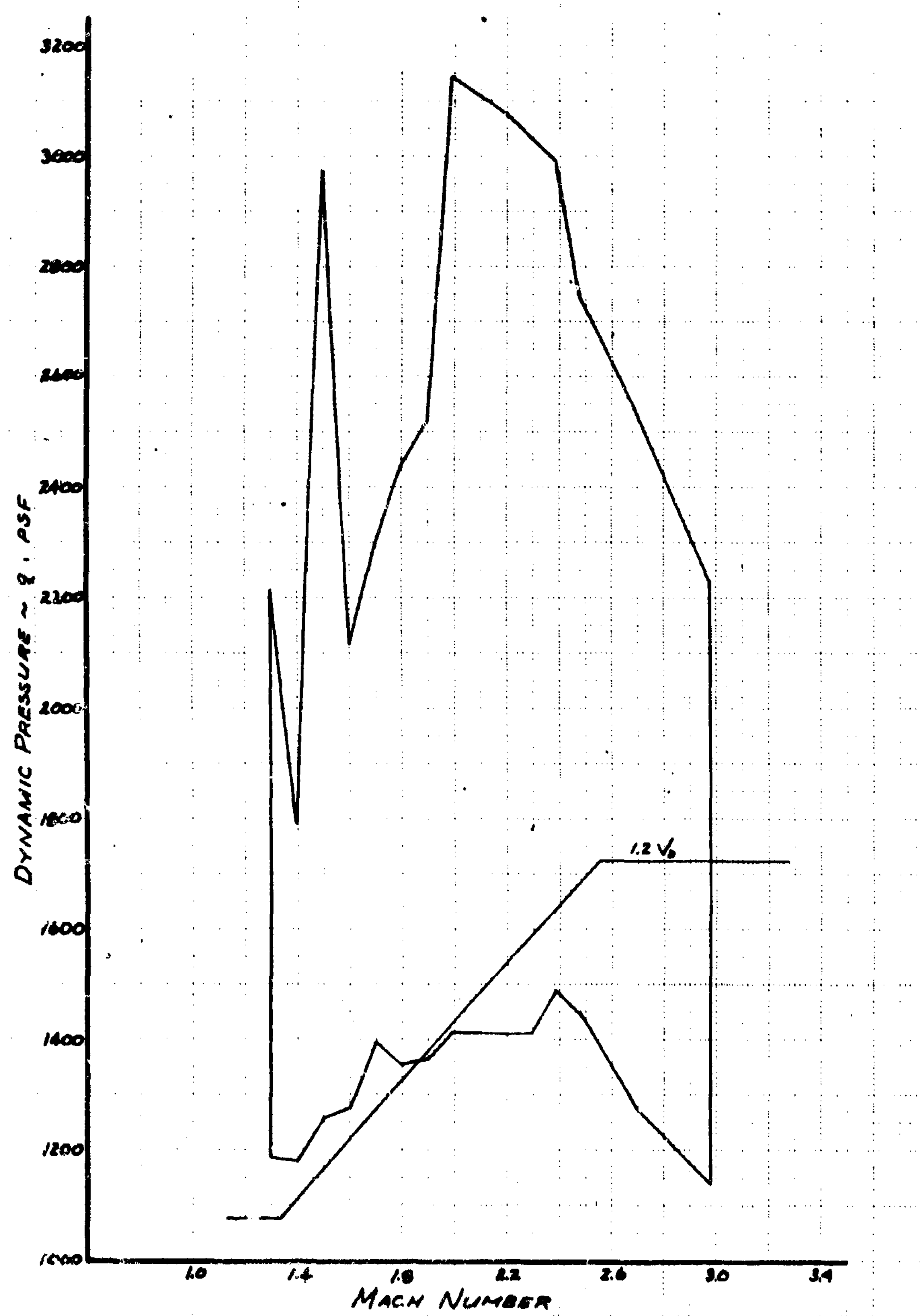


Figure 67. Vertical Fin Test Envelope Boeing Supersonic Wind Tunnel

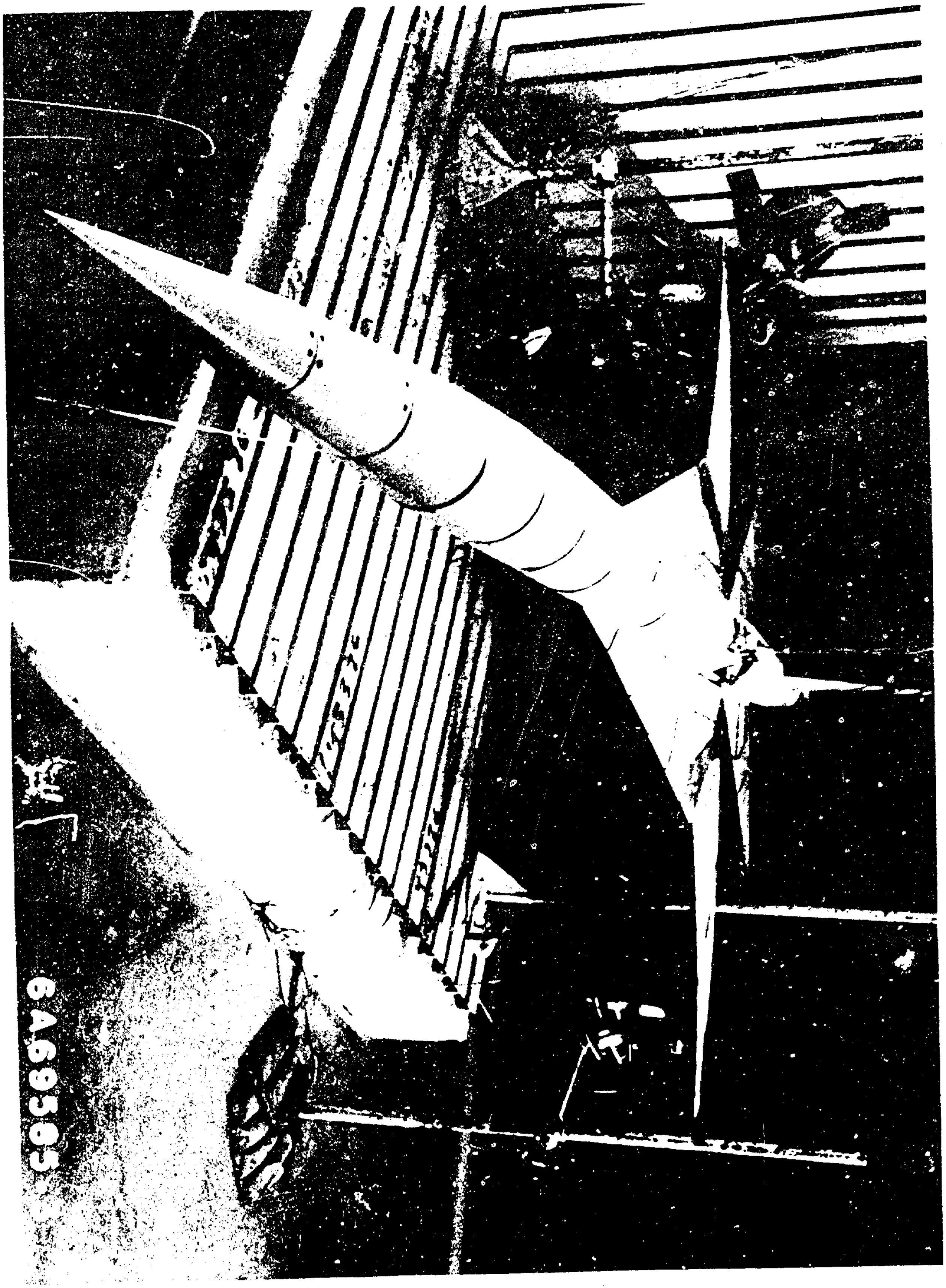


Figure 68. .05 Scale Subsonic Fultter Model Testing

III. Description of Technical Progress (continued)

1101. Wing (continued)

(2) Fail-safe testing of a 12-foot lower surface wing panel is sheduled to begin in early August.

(3) The life-test program for the first full-size wing-pivot bearing has been terminated. At 30,101 cycles, a crack developed along the highly loaded edge of the titanium lug of the bearing support fitting. This crack is in the same lug that had previously been repaired by welding but not in the same location. The lugs have been removed from the test fixture and are being disassembled. Electrical resistance measurements across the bearing races, taken during cycling testing, indicate the bearing is in good condition. The pivot bearing is being removed for a detail inspection.

As previously reported, a new Ti 6Al-4V pivot lug is being built to life-test the second full scale pivot bearing. Testing is expected to begin late this year.

(4) In the quarter-scale wing-pivot bearing development program, testing of bearings 11 and 12 (three-piece bearing of the -3 modified configuration referred to in the May Progress Report) is in progress.

After the bearings had accumulated 300,000 cycles, the test pressure was increased from 8,850 psi to 12,500 psi, and the cyclic rate decreased from 6 cpm to 5 cpm to maintain a 300°F bearing temperature. At 400,000 cycles, the bearings were removed from the test fixture for inspection. Wear measurements taken at this time showed that 90 percent of the bearing liner remained. The bearings will be reinstalled and testing will continue.

1104. Fuselage

The nose mockup using a single pivot has been reviewed. It was determined that the increased nose deflection from the higher approach angles resulted in insufficient ground clearance. Therefore, a second pivot was added near the top surface of the nose forward of the forebody windshields. The area ahead of the second pivot contains the weather radar and the pivot probe. The alignment of each piece of equipment is maintained by synchronization between forebody segments during nose rotation. The mockup is currently being revised to reflect these improvements.

Section 41 full-size cab test hardware program is on schedule. Detail parts are currently in fabrication at Norair.

Further adjustment of the relative position of the wing on the body has made possible two favorable structural features:

III. Description of Technical Progress (continued)

1104. Fuselage (continued)

(1) A common station has been established for the forward end of the wing and body fuel tanks. As a result, side fuel wall exposure to pressurized monocoque skin in the lower lobe is eliminated.

(2) Since the strake upper contour is always below the passenger floor, a structural connection at that contour simplifies strake rib structure without body frame penalty.

Skin panel drawings were released to Manufacturing for fabrication of test panels to be used for crack propagation testing.

1106. Landing Gear

A survey trip was made to Loud Company, Pamona, California, Cleveland Pneumatic Company, Cleveland, Ohio, Bendix Corporation, South Bend, Indiana, and Jarry Hydraulics, Montreal, Canada. The survey team was composed of members of Boeing Materiel, Finance, Manufacturing, Quality Control, and Engineering departments. The purpose was to obtain background data and on-site visual inspection prior to receipt of vendor proposals.

Proposals have now been received and are being evaluated. Proposals were made for the nose and main gears by Bendix and CPT. Loud submitted a proposal on the nose gear only. Jarry did not propose, due to lack of preparation time.

1107. Power Plant Structure

11070. GENERAL

Thirteen layouts of mount systems were made to establish support geometry and interface with the candidate engines. The mount systems for the P&WA JTF17A-21B engine is shown on layout P-ENG-576. The layout P-ENG-585 defines the front mount, and P-ENG-581 defines the rear mount for the GE4/J5P engine.

The mount systems for both engines incorporate vibration isolators and a thrust link with an integral force cell which is used in the thrust indication system.

11071. ENGINE COWL

Two layouts were made showing alternate methods of supporting the engine cowling. Comparison of engine mounted versus airframe mounted resulted in the selection of the engine mounted cowl supports for the proposal configuration. Nonpressurized cowling is used for

11071. Engine Cowl (continued)

both engine installations.(Refer to Par.13073.)Layout P-ENG-590 shows the cowling for the GE4/J5P engine and layout P-ENG-586, the cowling for the P&WA JTF17A-21B engine. These layouts define the cowling for the proposal airplane.

1108. Empennage

Studies and design of stabilizer structures have continued. A satisfactory structure arrangement, compatible with structural and systems requirements, has been developed.

Study layouts of wing interlock fittings have been completed. Elevon support structure and engine support structure design layouts are being developed.

Mockup drawings have been released, and mockup coordination to develop systems and structures interface requirements is continuing.

12. AIRFRAME SYSTEMS

1202. Environmental Control System (ECS)

(1) Compressor Development Program

The program for development and test of the cabin air compressor is proceeding on schedule. A 1-day demonstration of the compressor performance and operating characteristics is scheduled for September 15, 1966.

A meeting was held with the Environmental Control System Airline SST Committee on June 1, 2, and 3, 1966, to review the system design. The committee comments and recommendations are being evaluated.

In accordance with the Detailed Work Plan, the following has been accomplished:

- Initial release of drawings for components and assemblies of the ECS Class I mockup have been made.
- Drawings of the flight deck air outlets for the crew cabin display mockup have been released.

(2) System Design

The following system modifications were made to accommodate the B-2707 configuration:

(a) The system was resized to accommodate heating, cooling, and ventilation requirements for the increased passenger load (increase in air flow rate from 4,400 cfm to 6,000 cfm for passenger cabin).

1202. Environmental Control System (ECS) (continued)

(b) The cooling units were relocated from the wing to the forward section of the horizontal stabilizer.

(c) The primary and secondary air-to-air heat exchangers were arranged to allow use of a common ram cooling air scoop. This reduced the number of ground cooling fans from eight to four. The electrical power requirements for ground operation of the system have been reduced by 80 KW by changing the electrically driven ground cooling fans to air turbine driven fans.

(d) The system has been modified to provide increased cabin flow during pressure shell failure conditions, which permits deletion of the passenger oxygen system. A high-flow mode, initiated by the cabin pressure control system altitude rate-of-change sensor, is incorporated within the cabin air boost compressor flow control. This supplemental air is bypassed around the air cycle machine and discharged back into the cabin supply air duct. With three cooling systems operating, the increased airflow limits the cabin altitude transient following a structural blowout (42 in.^{2}) from exceeding 14,000 feet. Cabin air temperature will increase from 75°F to approximately 80°F during the rapid descent.

1203. Hydraulic Systems

The hydraulic pump proposal evaluation has been completed and purchase orders placed with American Brake Shoe and Vickers, Inc., for delivery of one pump each by March 15, 1967. These pumps are being designed and developed on a vendor participation basis.

The 70-GPM Bendix Pump failed during the calibration test and was returned to the vendor for evaluation and comment. The Vickers 50-GPM pump has completed 410 hours successfully.

Moog Servocontrols, Inc., has been selected to design and develop the master control servo. Accordingly, a purchase order was issued June 22 for a unit to be delivered December 5, 1966.

The Dow Corning XF-10294 fluid pump loop system was shut down because of excessive case leakage at 408 hours. The leakage was caused by case separation due to pullout of the thread inserts. A red residue was found on the pump hanger during teardown. Further testing of this fluid has been suspended, pending a report by Dow Corning.

Following failure of the ETO 5251 in the valve stiction test, Humble Oil has formulated a new fluid (WSX 6885) similar to ETO 5251 except that it has a greatly improved oxidation temperature. This fluid has completed 75 cycles in the valve stiction test, and a pump loop test was started July 26 to verify fluid characteristics in a system.

III. Description of Technical Progress (continued)

1204. Flight Control System

The Flight Controls and Hydraulics subsystem specification (D6A10120-1) was completed and a preliminary release forwarded to the FAA for comments. No comments have been received; however, the specification is being updated to reflect the latest subsystem data for the final release.

Block diagrams for the primary and secondary flight control systems have been established for the competition configuration and detail design studies of actuation, control and programing are being performed.

The preliminary equipment failure and human error analysis for all the flight control subsystems has been completed. A summary analysis chart of the combined flight control, hydraulic, and automatic flight control systems is being prepared. A preliminary flight control subsystem reliability analysis has been completed except for the high lift and nose tilt subsystems, which are approximately 75 percent complete.

Design proposal data for the wing-sweep actuator and wing-sweep power control unit in response to a preliminary procurement specification has been received from one prospective supplier and is being reviewed. Design proposals from three additional suppliers are expected within 2 weeks.

The wing-sweep and high-lift control system has been revised to separate the functions so that two control levers are now utilized rather than a single integrated control lever. The revision was occasioned by information on operation of the F-111 wing-sweep control system where confusion on direction of lever operation to sweep wings resulted in pilots operating the wings in the opposite direction to what was desired. To accomplish the desired direction of lever operation (forward movement for wings forward and aft movement for wings aft) it was necessary to add a separate wing-sweep lever.

The stability augmentation servo package for the Bertea horizontal stabilizer servo development unit has been received for testing and preliminary tests are underway. The site for the Bertea servo test rig design is being modified to suit the area selected.

A swivel test program of a new swivel incorporating more easily installed seals, will begin in early August. This test of 300,000 cycles is scheduled for completion in December 1966.

III. Description of Technical Progress (continued)

1205. Electrical Systems

12051. BONDING AND GROUNDING

Analysis of the basic structure indicates that the structure is more than adequate as a basic current return circuit. Further reduction of the current return path resistance is accomplished through the use of aluminum seat tracks, which are bonded to the basic structure. Because of the above, it has been decided to use the airplane basic structure as the current return path except where circuit sensitivity, EMI, or other considerations require separate ground return.

Battelle Northwest was contacted for submittal of a research program proposal for investigating interface procedures to be followed when mounting aluminum alloy components to titanium structure. Their proposal is due shortly.

12052. ELECTRICAL POWER SYSTEMS

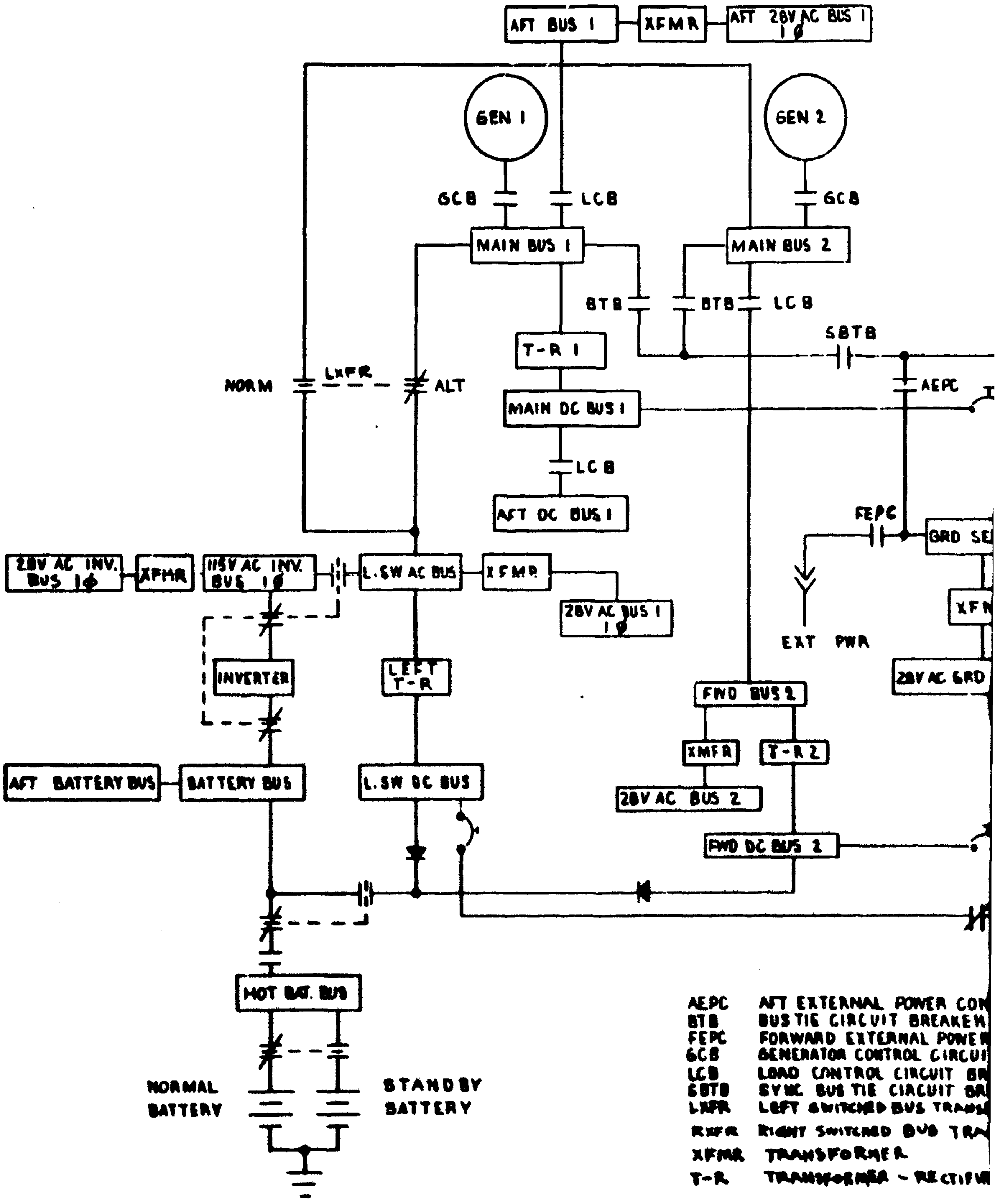
The electrical power generation and distribution circuits were updated to incorporate the latest design changes. The resultant schematic is shown in Fig. 69. These revisions represent circuit refinement and do not affect the electrical power and distribution system basic concepts. The external power circuit was revised as follows:

(1) There will be one external power receptacle and it will be located in the nose wheel well area.

(2) A ground power feeder system will transmit ground power from a receptacle located near the nose wheel well to a point on the sync bus, which is located in the center electrical equipment bay. Power transmitting capability of this feeder system will be 90 kva.

(3) There will be a contactor at both ends of the feeder system. The contactor at the receptacle end will permit controlled application of ground power to the airplane buses and will provide an isolation point to aid in establishing fault location. The contactor at the sync bus end will permit isolation of the ground power feeders from the airplane bus system. Thus, the approximately 240 feet of ground power feeders will not be a potential inflight fault source to the airplane bus system.

Fuel pumps were reassigned among the main ac buses to ensure that loss of a bus will not remove power from more than one pump in any tank.


AFT BUS 1
XFMR
AFT 28V AC BUS 1 1Ø
GEN 1
GEN 2
GCB
LCB
GCB
MAIN BUS 1
MAIN BUS 2
BTB
BTB
LCB
SBTB
T-R 1
AEPC
NORM
LXFR
ALT
MAIN DC BUS 1
LCB
AFT DC BUS 1
FEPC
28V AC INV. BUS 1Ø
XFMR
115V AC INV. BUS 1Ø
L.SW AC BUS
XFMR
28V AC BUS 1 1Ø
EXT PWR
INVERTER
LEFT T-R
FWD BUS 2
XMFR
T-R 2
28V AC BUS 2
AFT BATTERY BUS
BATTERY BUS
L.SW DC BUS
FWD DC BUS 2
HOT BAT. BUS
NORMAL BATTERY
STANDBY BATTERY
AEPC AFT EXTERNAL POWER CON
BTB BUS TIE CIRCUIT BREAKER
FEPC FORWARD EXTERNAL POWER
GCB GENERATOR CONTROL CIRCUI
LCB LOAD CONTROL CIRCUIT BR
SBTB SYNC BUS TIE CIRCUIT BR
LXFR LEFT SWITCHED BUS TRAN
RXFR RIGHT SWITCHED BUS TRA
XFMR TRANSFORMER
T-R TRANSFORMER - RECTIFIE

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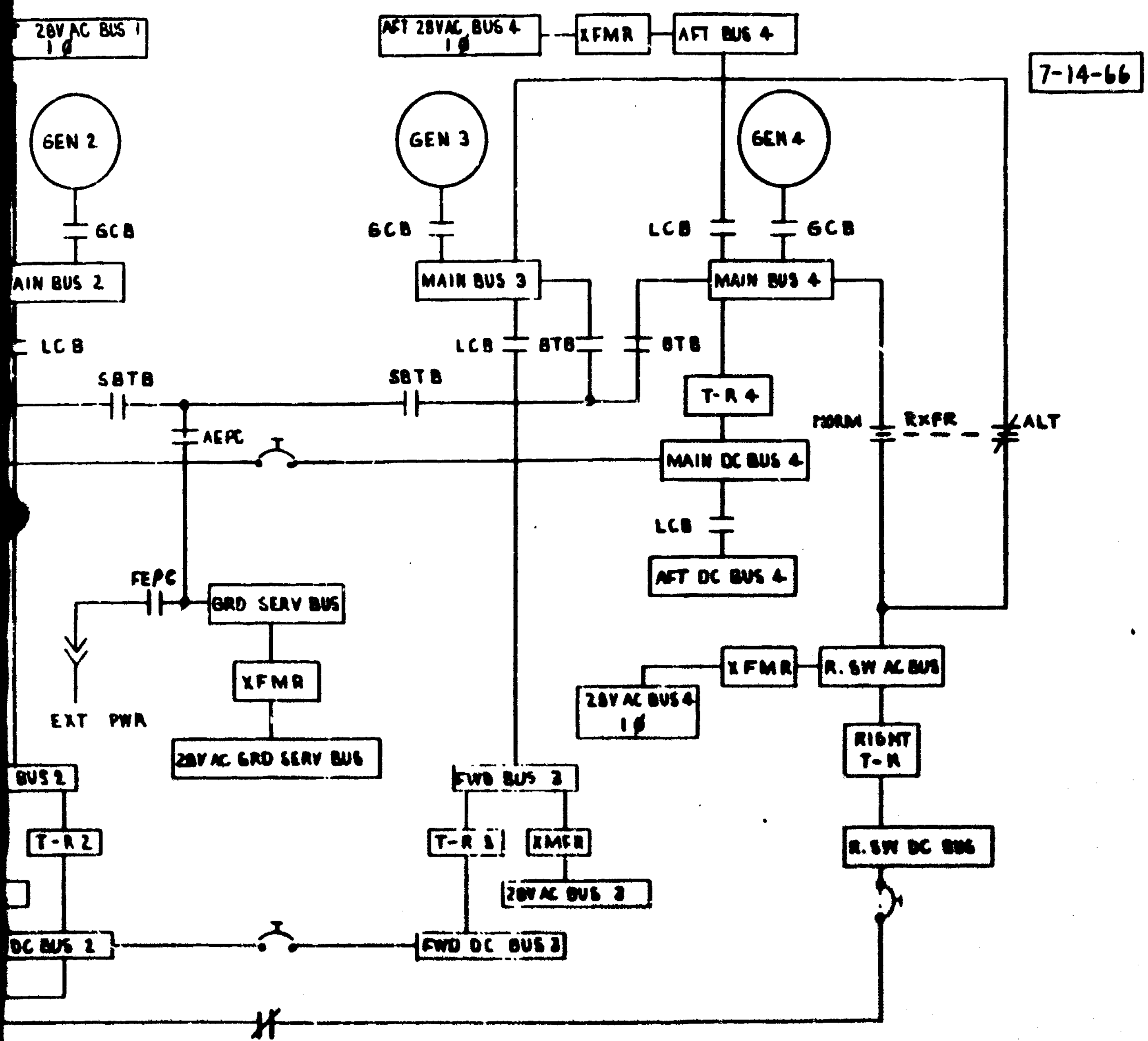


AFT EXTERNAL POWER CONTACTOR
BUS TIE CIRCUIT BREAKER
FORWARD EXTERNAL POWER CONTACTOR
GENERATOR CONTROL CIRCUIT BREAKER
LOAD CONTROL CIRCUIT BREAKER
SYNC BUS TIE CIRCUIT BREAKER
LEFT SWITCHED BUS TRANSFER CONTACTOR
RIGHT SWITCHED BUS TRANSFER CONTACTOR
TRANSFORMER
TRANSFORMER - RECTIFIER

Figure 69. Electrical Power Generation and Distribution—SST Model B-2707

B

III. Description of Technical Progress (continued)

12052. Electrical Power Systems (continued)

A revised estimate of electrical loads has required an increase in the rating of the primary electric power supply. Four variable speed constant frequency channels, each capable of supplying 60 kva to the airplane, are provided. The airplane is dispatched with three of these channels capable of operation.

A "Bus Schedule of Operation" study was completed. This study includes normal and abnormal conditions, including smoke clearing operation. In addition to serving as an engineering design tool, it substantiates the feasibility of utilizing existing electrical system controls, available to the flight crew, to isolate sections of the distribution system. This provides for smoke clearing procedures and permits isolation of a faulted portion of the distribution system so that the remaining portion can continue to function.

Packaging studies of hardware arrangement and assembly have been made to determine the most expeditious and advantageous manner of implementing the electric generation and distribution circuit design into a practical airborne hardware system.

Further refinements have been made in the generator oil cooling trade study; the best overall choice appears to be an independent oil circuit with the pump located within the generator housing. The choice is based on maintainability, dispatch reliability, and minimum interference with basic functioning and reliability of the accessory drive system.

Progress and status reports have been received from the two vendors engaged in the development of a high-speed, oil cooled variable speed generator. Both vendors have completed the preliminary design phase and are concentrating on specific design tools defined by the contract.

An equipment failure and human error mode and effect analysis was conducted to determine the consequence of single and multiple failures in the electric power subsystem. This analysis is continuing to a lower level of detail. It is concluded from the analysis that no single failure or abnormal condition will result in loss of electric power capacity or load equipment sufficient to require a change in flight plan. Four channels of primary ac power, separation of the primary dc power system T-R units and distribution, and switched buses ensure continuity of power to essential flight loads in the event of multiple electric power subsystem failures. Standby power provisions ensure continuity of power to critical safety-of-flight loads in the event of total loss of the mechanical power input to the electric power subsystem or all-engines-out conditions.

III. Description of Technical Progress (continued)

12052. Electrical Power Systems (continued)

An advanced control panel configuration using a pushbutton concept has been designed for possible use for the VSCF generating systems. The detailed arrangement of the panel is shown in Fig. 70. The control system is the same as the standard panel, except that the control is by pushbuttons instead of toggle switches. From a human factors standpoint, the pushbutton panel is easily understood, clearly represents the power system configuration, and is easier to operate than the standard control panel. The separation between generating channels and the systems interconnections are readily visible. The generating controls (mechanical disconnect, generator off, and generator on) will be guarded to prevent inadvertent operation.

12053. AUXILIARY ELECTRICAL SYSTEMS

Remote Circuit Breaker

Proposals in response to 10-61118, Remote Circuit Breaker specification, were evaluated during the first part of June.

These proposals indicate that the design of remote circuit breakers is feasible; however, indications are that solid-state breakers would be limited to 20 amperes dc and 5 amperes ac.

The remote circuit breaker specification will be updated and resubmitted to the suppliers and a development program initiated early in the Phase III program.

Multichannel Control and Indicating System

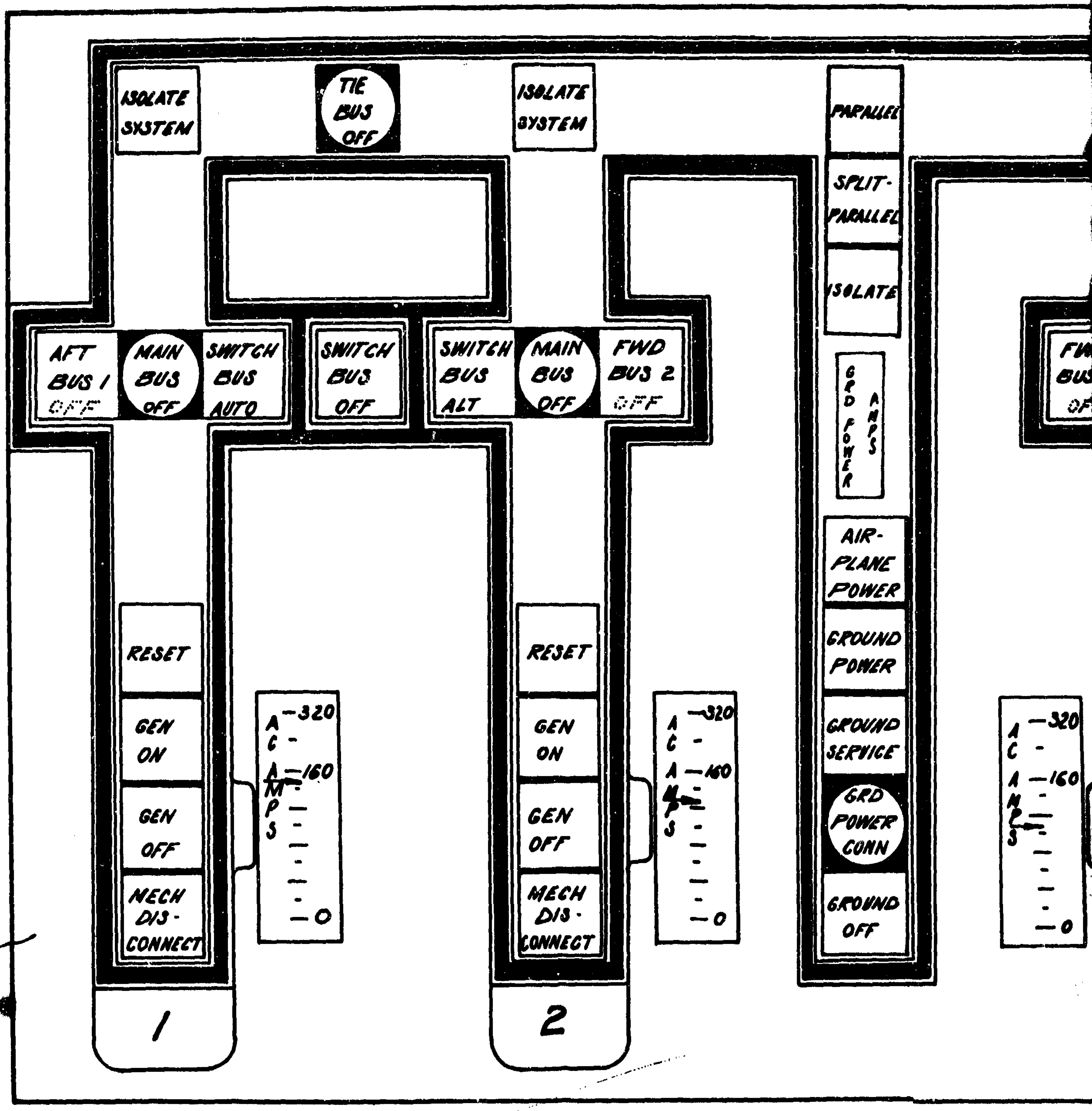
One proposal has been received in response to procurement specification 10-60981, Multichannel Control and Indicating System. The weight and reliability of the proposed system were not consistent with the requirements for the B-2707. We are now investigating a multiplexing system that contains mostly integrated circuits. It is believed that the use of a large number of integrated circuits may yield a multiplexing system of low weight and high reliability.

Proximity Switches

The Proximity Switch specification, 60A10001, will be updated, and development work will resume early in the Phase III program.

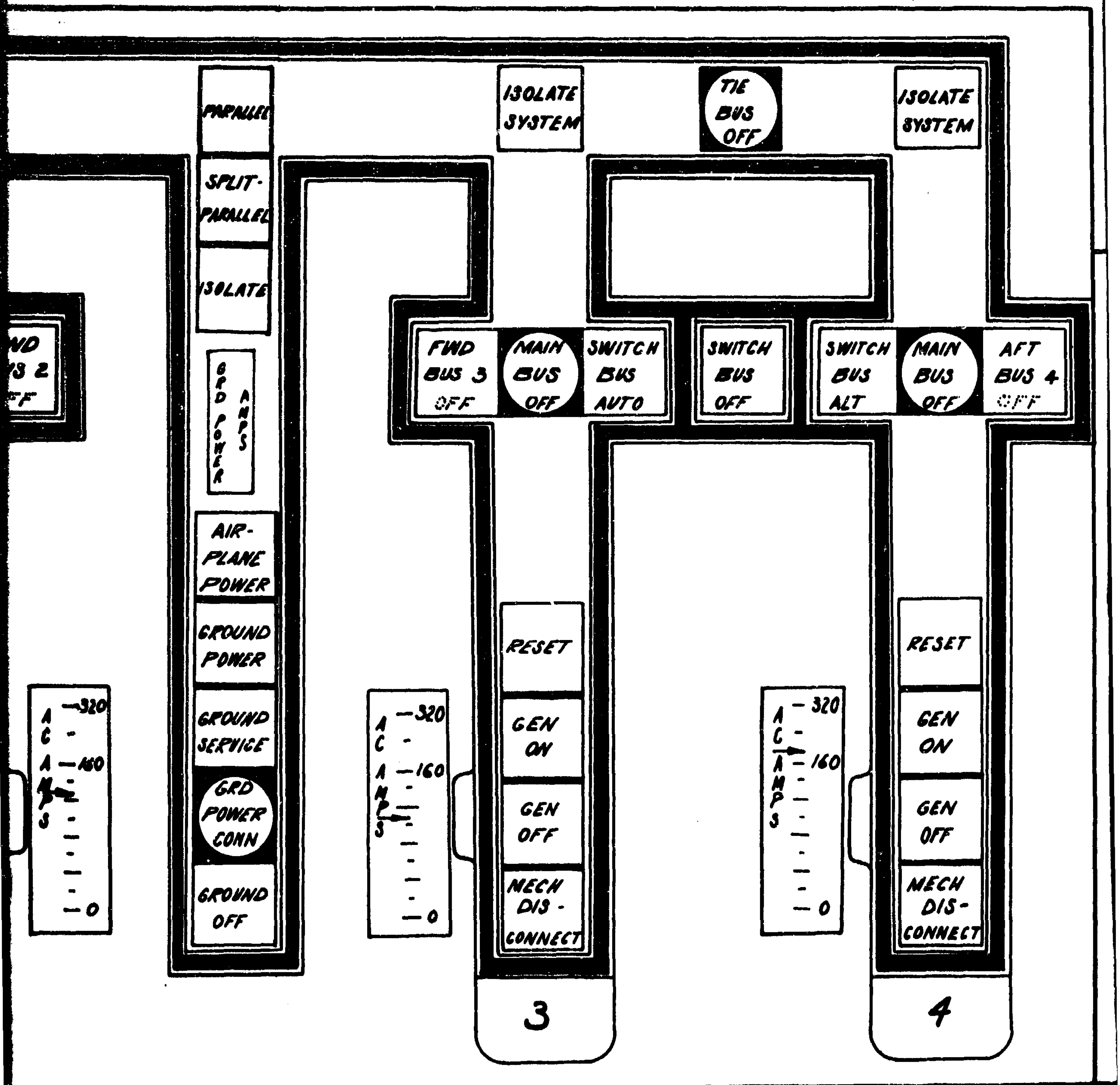
12056. WIRING AND TERMINATIONS

Major fore-aft raceways have been relocated from the center floor location to the overhead. This relocation was accomplished to improve safety by separating wiring from the body fuel cell. The wire raceways are located in the ceiling, one left and one right, approximately 20 inches from the centerline. Each raceway is divided into sections with built-in separators. Power wiring is routed in the right-hand raceway and signal wiring in the left.



ISOLATE SYSTEM
TIE BUS OFF
ISOLATE SYSTEM
PARALLEL
SPLIT-PARALLEL
ISOLATE
AFT BUS 1 OFF
MAIN BUS OFF
SWITCH BUS AUTO
SWITCH BUS OFF
SWITCH BUS ALT
MAIN BUS OFF
FWD BUS 2 OFF
GRD POWER AMPS
AIR-PLANE POWER
GROUND POWER
GROUND SERVICE
GRD POWER CONN
GROUND OFF
RESET
GEN ON
GEN OFF
MECH DIS-CONNECT
AC AMPS
320
160
0
RESET
GEN ON
GEN OFF
MECH DIS-CONNECT
AC AMPS
320
160
0
AC AMPS
320
160
0
1
2

A


PARALLEL
SPLIT-PARALLEL
ISOLATE
GRD POWER AMPS
AIR-PLANE POWER
GROUND POWER
GROUND SERVICE
GRD POWER CONN
GROUND OFF
A C AMPS
320
160
0
ISOLATE SYSTEM
TIE BUS OFF
ISOLATE SYSTEM
FWD BUS 3 OFF
MAIN BUS OFF
SWITCH BUS AUTO
SWITCH BUS OFF
SWITCH BUS ALT
MAIN BUS OFF
AFT BUS 4 OFF
A C AMPS
320
160
0
RESET
GEN ON
GEN OFF
MECH DIS-CONNECT
3
A C AMPS
320
160
0
RESET
GEN ON
GEN OFF
MECH DIS-CONNECT
4

B

Figure 70. Advanced Control Panel Configuration

III. Description of Technical Progress (continued)

12056. Wiring and Terminations (continued)

The engine wire harnesses consist of metal jacketed cables for the engine-mounted components and a MIL-W-7139E type wire for the cable assemblies installed between the engine case and the fire-wall. One end of the cable will terminate at the engine-mounted component with the opposite end terminating in an interface box located on the upper surface of the engine. Hard harnesses are bench wired and bench tested prior to engine installation. Engine circuits can be isolated from airplane circuits for trouble shooting by disconnecting the cables at an interface plate.

Alternate methods of routing the electrical wiring in this area have been investigated. As a result, a design concept of routing the wire harnesses through the pivot area adjacent to the other systems seems to be the most favorable approach.

The design consists of separating electrical systems into several flexible teflon lined conduits. The outside braid will be used as redundant ground return paths.

12057. ELECTRICAL EQUIPMENT-GENERAL

The electrical bay and aft electronics bay have been combined and relocated to an area aft of the passenger compartment. This relocation was made to provide maximum isolation of primary electrical components and wiring from fuel in the event of a wheels up landing. This relocation also provides inflight access, improved access for ground maintenance, and obviates the need for pressurized hatch in the lower lobe.

1206. Accessory Drive System (ADS)

(1) Development Program (ADS)

(a) Coordination meetings were held in Seattle with Hamilton Standard and Sundstrand on June 6-7 and June 9-10, respectively. Both contractors reported progress in component development testing and were confident that the Demonstration Tests scheduled for September (FAA informed of September and October dates) would be conducted on time.

(b) Both Hamilton Standard and Sundstrand have [illegible] reports for the final design of their ADS units.

(2) Accessory Drive System

The cooling of the four ADS [illegible] cabin intrawall exhaust and fuel to using [illegible] for all four units. This change was made [illegible] cabin intrawall exhaust air made available [illegible] 733-414 to the B-2707 airplane, which in[illegible]

III. Description of Technical Progress (continued)

1206. Accessory Drive System (ADS) (continued)

(3) Gas Turbine Starter

An onboard APU for self-sufficiency is still being evaluated as optional equipment. Further vendor - Boeing coordination is scheduled for early August.

(4) All-Engine-Out Controlability

The Pratt and Whitney engine is capable of supplying sufficient windmilling power to control the airplane, including takeoff and landing. The General Electric engine is not capable of supplying sufficient power so a ram air turbine will be required to provide additional power for takeoff, descent, and landing in an all-engine failure. The turbine-driven pump will be mounted on a door, which will provide structural support in the deployed position.

1207. Automatic Flight Controls

General Electric has been added to the vendor list for proposal on the SST AFCS at their request and will submit their proposal on August 1, 1966. Critiques on the proposals submitted by Bendix, Honeywell, and Sperry-Phoenix have been returned to the vendors for response by August 1, 1966.

A preliminary design review on the AFCS was held July 7, 1966. Critiques from this review are being studied for incorporation into the design.

The detail work plan item 2190, Reliability Analysis Document (D6A10064-4), is being completely revised and will be forwarded to the FAA in early August. Detail work plan item 2180, critical SAS Failure Modes, will be included in the above document.

1208. Flight Deck Installations and Systems

The Phase II-C development mockup has been completed and was reviewed by the FAA on June 24 and by the airlines subcommittee on June 28, 1966. Review of comments and change requests is complete. Minutes of the June 24th Preliminary Design Review have been sent to the FAA.

12081. INSTRUMENT AND CONTROLS ARRANGEMENTS AND DISPLAYS

Document D617850, B-2707 SST Model Specification, was reviewed with Pan American and TWA representatives. Approximately 30 airline requests are under consideration for appropriate action.

III. Description of Technical Progress (continued)

12083. RAIN REMOVAL SYSTEM

Trade studies conducted have led to the selection of windshield wipers, rather than air blast. Document D6A10137-1, Rain Removal System, is in draft form. Publication is planned in August.

12084. PITOT STATIC SENSORS

In response to preliminary specification requirements, Rosemount Engineering Company has submitted a proposal. A system comprised of compensated nose-mounted pitot-static probes, body mounted pitot-probes, and flushstatic ports has been selected for the prototype airplane.

12085. AIRPLANE SURVIVABILITY/ESCAPE SYSTEM STUDY

Document D6A10167-1, Airplane Survivability/Crew Escape Studies Summary Report, dated July 20, 1966, is awaiting final approval.

Landing Simulation

Landing simulation studies are in progress at the Kent Space Center simulator. Current work is directed at assessing the effects of approach speed and angle of attack on pilot performance.

1209. Communications

The following document was released: D6A10064-5, B-2707 Reliability Analysis Document - Communications Subsystem.

Vendor proposals for the 10-60982 VHF antenna have been evaluated.

A failure effect analysis has been conducted on the HF and VHF communication system. The results of this analysis will be included in D6A10064-5.

Impedance measurements are being conducted to the HF notch antenna on a 0.10-scale model of the B-2707 configuration. Antenna impedance and efficiency will be determined for the 2- to 25-Mc band. A dielectric tower approximately 70 feet high is being used to minimize the undesirable effects of the earth.

The effect of doppler shift on SELCAL system operation was investigated. The results have indicated that doppler shift problems do not exist on ARINC 533A equipment.

1210. Navigation

The following document was released: D6A10064-12, Navigation & Flight Instruments-SST Reliability Document.

III. Description of Technical Progress (continued)

1210. Navigation (continued)

Vendor proposals in response to 10-60979, Air Data Displays have been evaluated.

A glide slope antenna system using two stub elements located in the forward wing root areas has been investigated. The stubs are connected to a hybrid ring to provide sum and difference outputs. Diode switches and latching circulators have been evaluated for switching the sum and difference outputs to the receiver.

Tests have been completed on a slot array glide slope antenna system using a hybrid ring for sum and difference patterns. Although this system is superior to a radome-mounted antenna, the wing root stub configuration has more suitable pattern characteristics.

Radiation patterns have been taken on a VOR/localizer antenna system using two interconnected stub elements located in the forward wing root areas and a single dipole in the tail cone. This system provides omnidirectional coverage for VOR and excellent forward coverage for the localizer mode. A high reliability solid-state switch alternately connects the tail cone and the stub antennas to the receiver during VOR operation. A major advantage of this configuration is the location of the localizer antenna near the center of gravity of the airplane.

A prototype solid-state switch was designed and tested for use with the hybrid ring coupled glide slope antennas. The switch is being investigated to verify feasibility, to minimize signal attenuation, and to prove capability of achieving the required operational reliability. Laboratory tests to date have shown no equipment degradation is experienced when using switching techniques if the proper switching frequency is chosen.

Technical and cost proposals have been received from six of the leading inertial system manufacturers in response to the revised procurement specification 10-60975, Inertial Navigator. These proposals have been evaluated and a summary report prepared. The proposals have indicated that the systems currently in development and available for the SST will consist of small, rugged, highly maintainable, conventionally gimballed platforms and light weight high-computation-speed digital computers. These systems will be capable of meeting the accuracy requirements consistent with the expected air traffic control environment.

Cost and technical data, in response to the 10-60972 Weather and Ground Mapping Radar preliminary procurement specification have been received. The proposals provided useful descriptive design detail and identified the antennas as the major development effort. Alternate

design approaches from the specification requirements were recommended in some instances. These recommendations are being evaluated.

1211. Electronics – General

Phase III test plans have been prepared for the communications and navigation equipment. These plans describe the design development, qualification, laboratory integrations, airplane ground integration, and 100-hour prototype flight test program for the B-2707. The major portion of the design development and qualification testing will be accomplished by the equipment suppliers with Boeing representatives monitoring and assisting as necessary to verify the competence of the test demonstrations. Integration testing will be conducted by Boeing utilizing the system laboratories, avionics test rig, and prototype airplanes to verify integrated system and subsystem compatibility and performance, develop functional and operational test procedures, and installation design. The 100-hour flight test program will evaluate the functional operation of the avionics on a limited noninterference basis within the primary objectives of the aircraft.

The AIDS mechanization trade study was completed. A design approach incorporating a digital computer, individually addressable data collection modules, single-line data transmission, magnetic tape recorder, hard copy printer, and display and control functions has been recommended.

A breadboard AIDS system consisting of a central address control function, several data conversion modules of various types, and a common transmission line is being fabricated. This breadboard system will be used for laboratory demonstration of the feasibility of the recommended system.

1212. Fire Detection System

12122. FIRE DETECTION SYSTEM

Six vendor proposals for the fire detection system have been reviewed and the heat sensitive, continuous dual element, shrouded detector system proposed by the Graviner Company has been selected for the Phase III program.

III. Description of Technical Progress (continued)

13. PROPULSION SYSTEMS

1300. Propulsion Systems, General

13001. POD FIRE PROTECTION SYSTEM

Layouts of firewall locations and isolation concepts have been made for each of the candidate engines. P-ENG-587 defines the isolation concept for the GE engine. P-ENG-588 reflects the P&WA engine isolation concept.

13002. POD MOCKUP

Layouts have been made for mockups of both candidate engine configurations. These basic mockups will be utilized for Class I developmental work during succeeding phases of the program. Pod lines for each engine have been released for Class I airplane mockup.

13003. POD SHAPE AND LOCATION

Pod shapes for both candidate engines have been defined for the proposal airplane configuration. In order to establish these pod shapes approximately 20 layouts covering both GE and P&WA engines were made during the reporting period. Close coordination was maintained between Aerodynamics Staff, Configuration, Propulsion Project, and Staff personnel in order to obtain the best possible pod shape. Various accessory arrangements have been investigated to best use the space available within the pod. Tests were conducted in BSWT to prove the feasibility of local modifications in the wing trailing edge. The proposal configuration eliminates a strut with its associated drag and permits over-the-wing reverser. P-ENG-582 defines the proposal pod configuration for the GE4/J5P engine. P-ENG-575 defines the proposal pod configuration for JTF17A-21B engine.

1301. Performance (Installed)

As a result of engine/airplane matching and design integration studies of engine data supplied by General Electric and Pratt and Whitney, the engines selected for the Boeing Phase III proposal are the GE4/J5P and JTF17A-21B. The respective engine manufacturers were notified of this selection on June 1, 1966.

1302. Air Induction System

(1) Inlet Test and Analysis

(a) One-Fifth Scale Model Testing

Testing to date with the solid centerbodies with vortex generators shows a circumferential scalloping of the total pressure recovery at the inlet compressor face. Various configurations of the

1302. Air Induction System (continued)

vortex generators have been tried to minimize this scalloping. Figure 71 shows a composite compressor face map with the optimum vortex generator pattern. The rake total pressure profiles shown at the bottom of Fig. 71 are for five rake positions behind different vortex generator arrangements (diverging or converging sets of vortex generators). The solid cruise centerbody with the vortex generators installed is shown on Fig. 72. The centerbody is shown installed in the inlet model on Fig. 73.

The variable diameter centerbody for the one-fifth scale model has been assembled and leak tested under simulated cruise pressure loads. The centerbody being readied for the leakage test is shown on Fig. 74. The boundary layer bleed holes on the centerbody were drilled after the leakage test. Results of the leakage test show that the leakage between seals on the centerbody under simulated cruise Mach number loads was 0.34 percent of the normal engine weight flow at cruise. The leakage rate with the highest pressure load found in any part of the inlet applied over the entire centerbody was 0.73 percent of the normal engine weight flow. Both leakage rates are for the centerbody fully expanded.

The tolerance of the inlet model to angle of incidence and Mach number changes without centerbody movement is shown on Fig. 75. The data was obtained at Mach 2.6 with the variable diameter centerbody. The curve shows that the inlet will tolerate a 0.05 Mach number decrease or a 2-3/4 degree change in angle of incidence without any inlet controller inputs.

(b) One-tenth Scale Low-Speed Testing

The B-2707 configuration has the flap systems in front of the inlets. The inboard inlet air supply comes from over the wing and down through a hole left in the wing strake by the inboard flap system. The performance of the inlet operating behind the inboard flap is shown on Fig. 76. The relationship of the inboard flap and inlet are shown on Figs. 77 and 78.

Total pressure recovery distribution at the compressor face with the flap fully extended at 175 knots is shown on Fig. 79.

The performance of the inlet as affected by auxiliary takeoff area is shown on Fig. 80. The performance shows that the optimum door size would be about 20 percent of the lip area. The curve also shows that the inlet performance would remain within acceptable limits as the auxiliary takeoff door is closed at 175 knots with the partial flap setting.

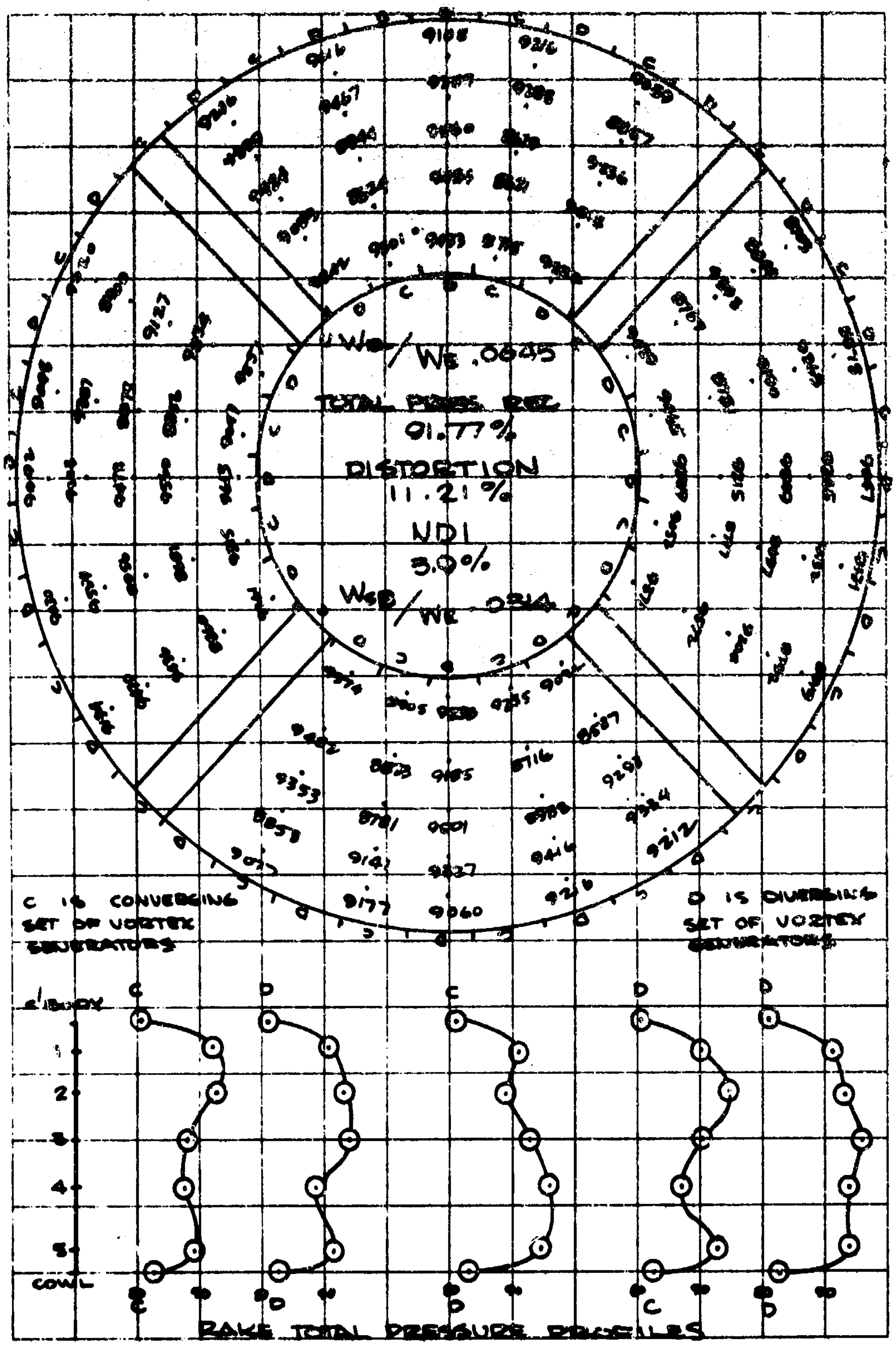


Figure 71. Compressor Face Map—Vortex Generator Effects

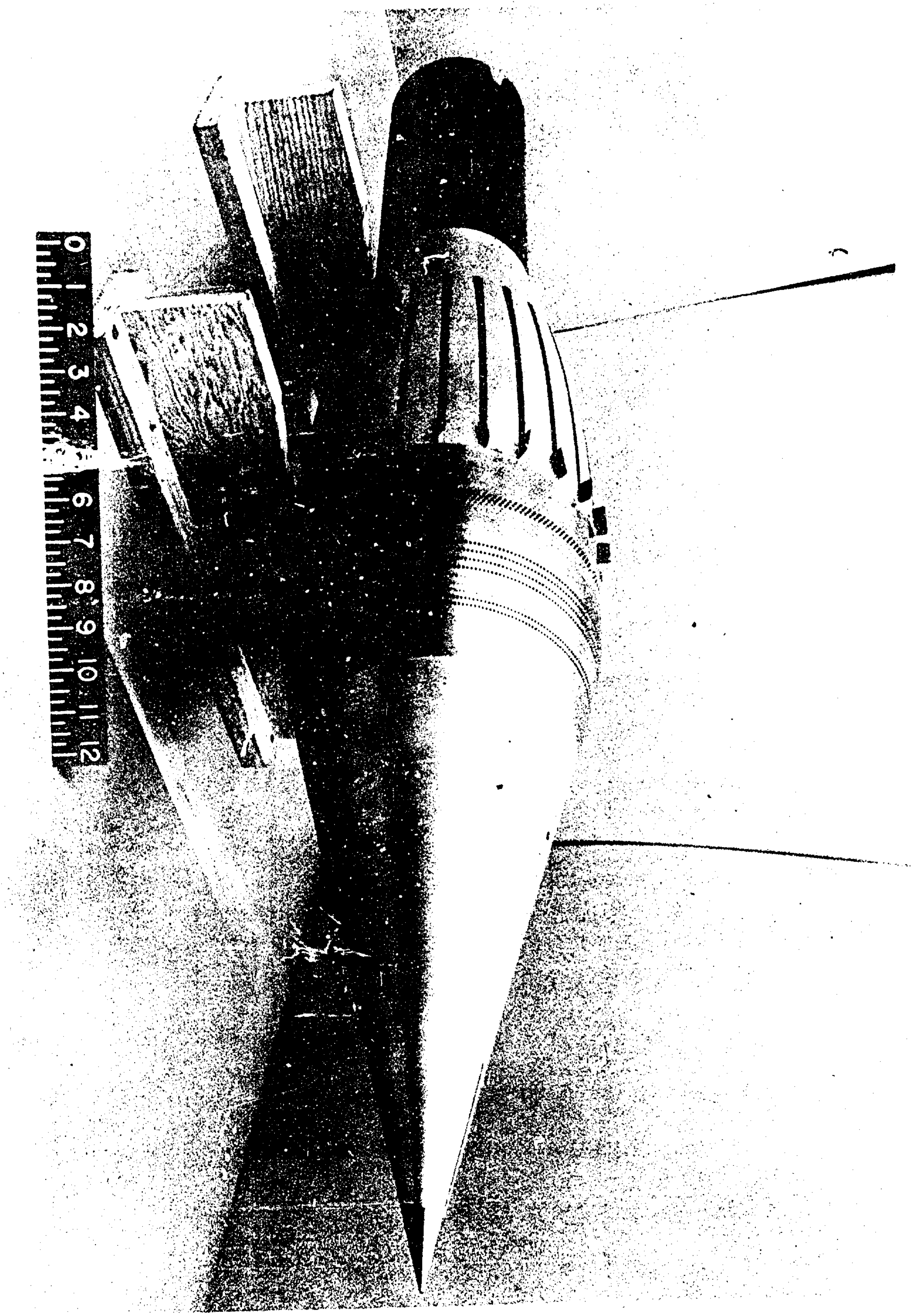


Figure 72. Centerbody With Vortex Generators

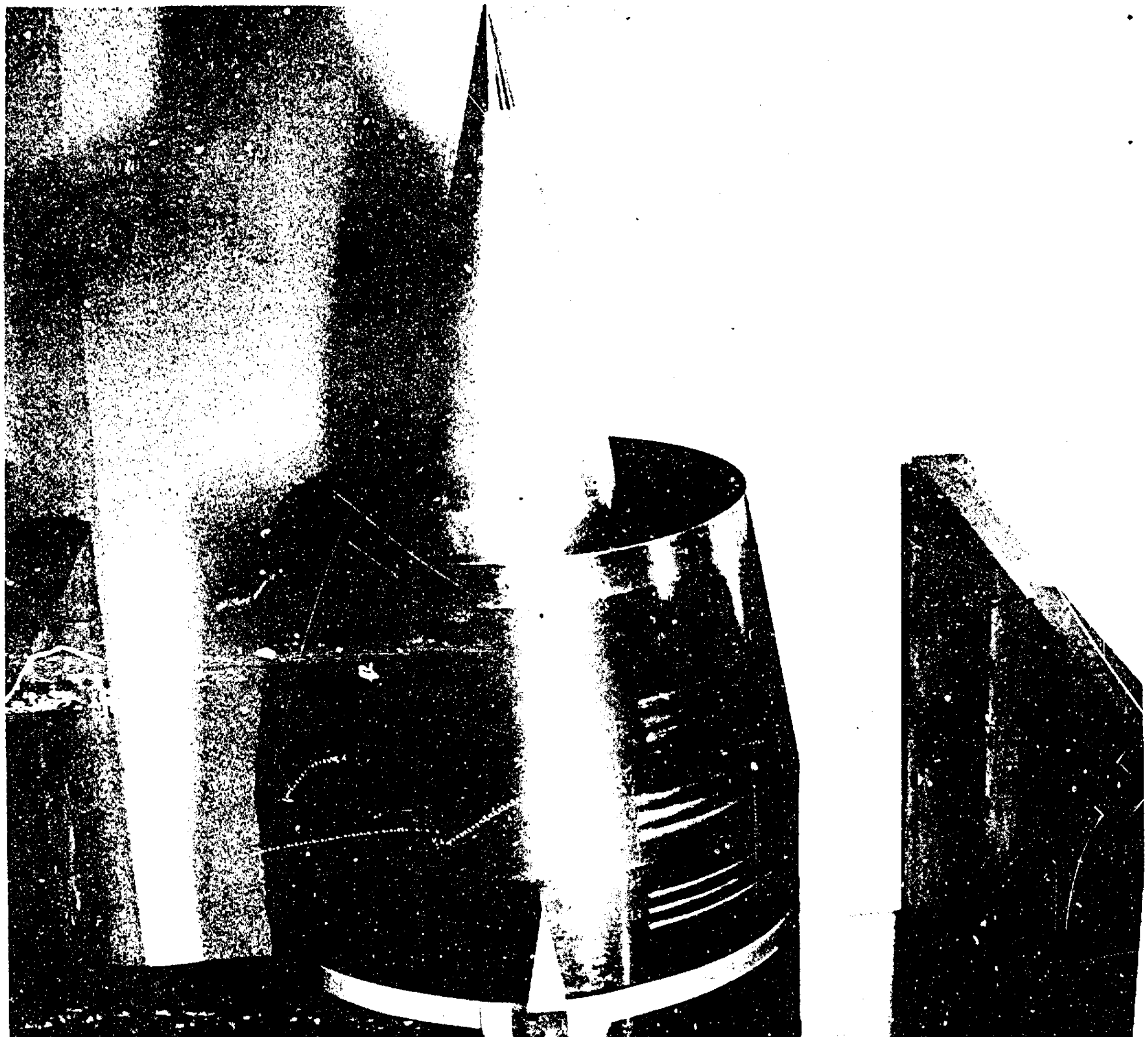


Figure 73. Inlet Model With Centerbody

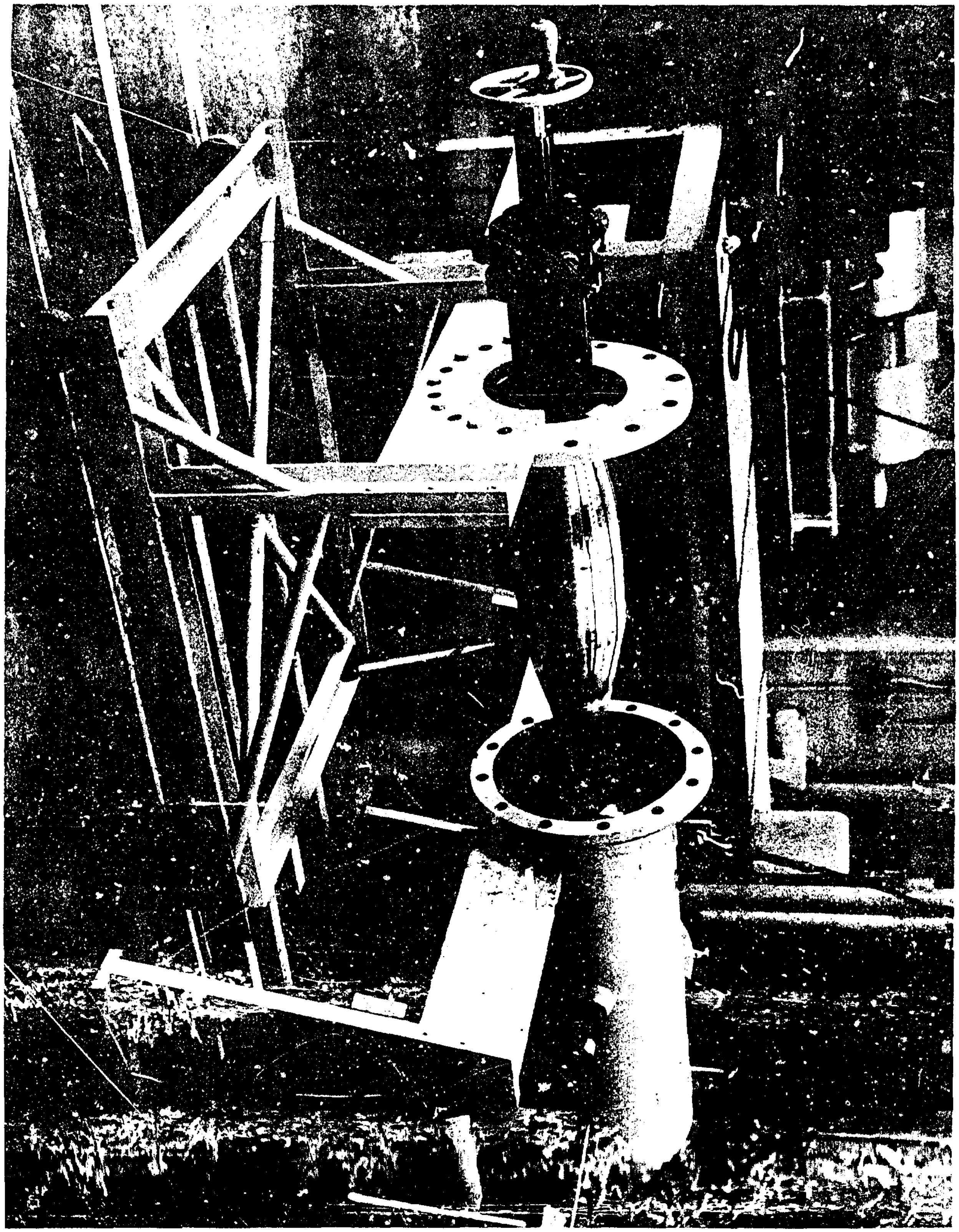


Figure 74. One-Fifth Scale Centerbody

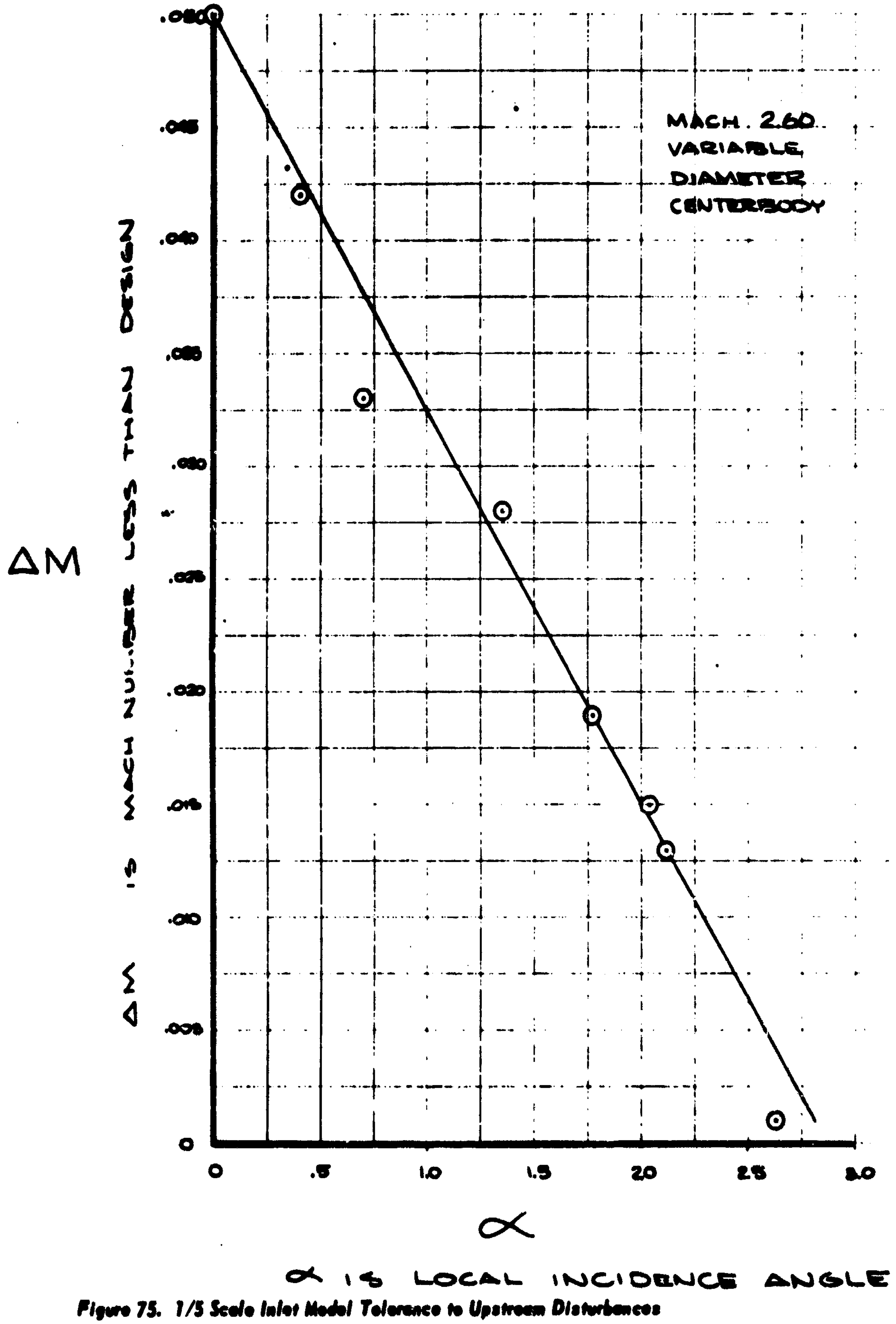


Figure 75. 1/5 Scale Inlet Model Tolerance to Upstream Disturbances

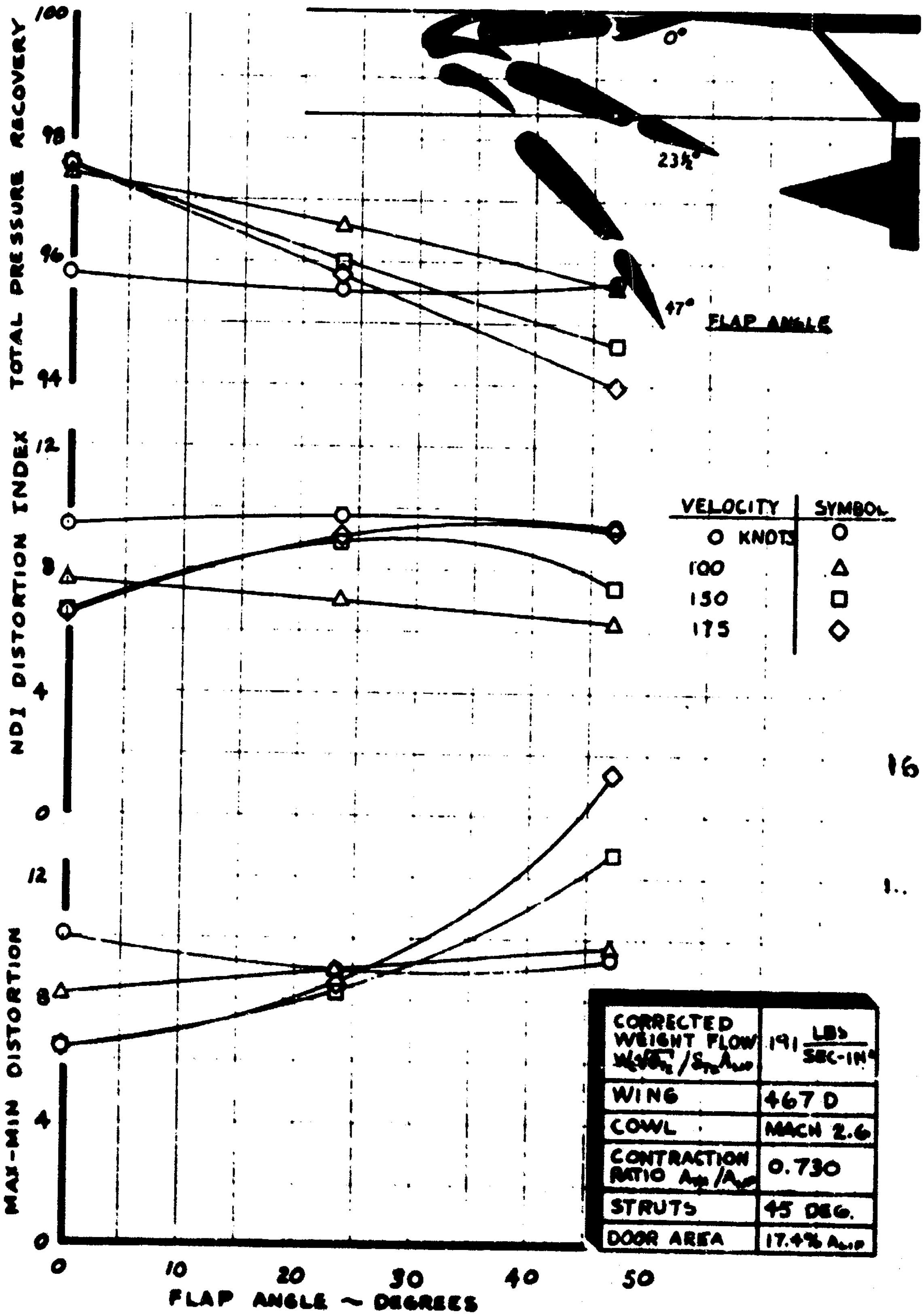


Figure 76. Low Speed Inlet Performance – Flap Transition

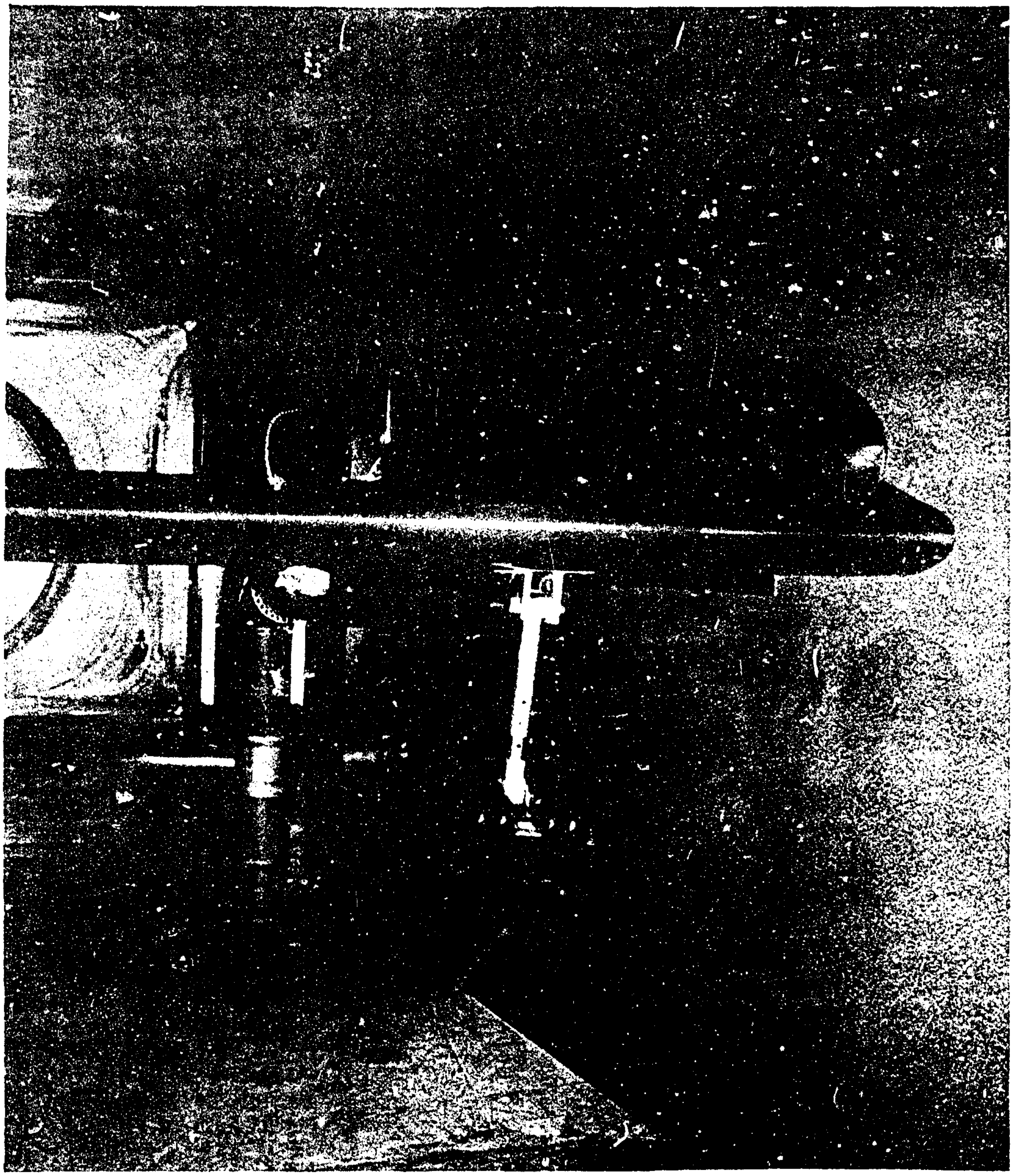


Figure 77. Inboard Flap and Inlet Relationship

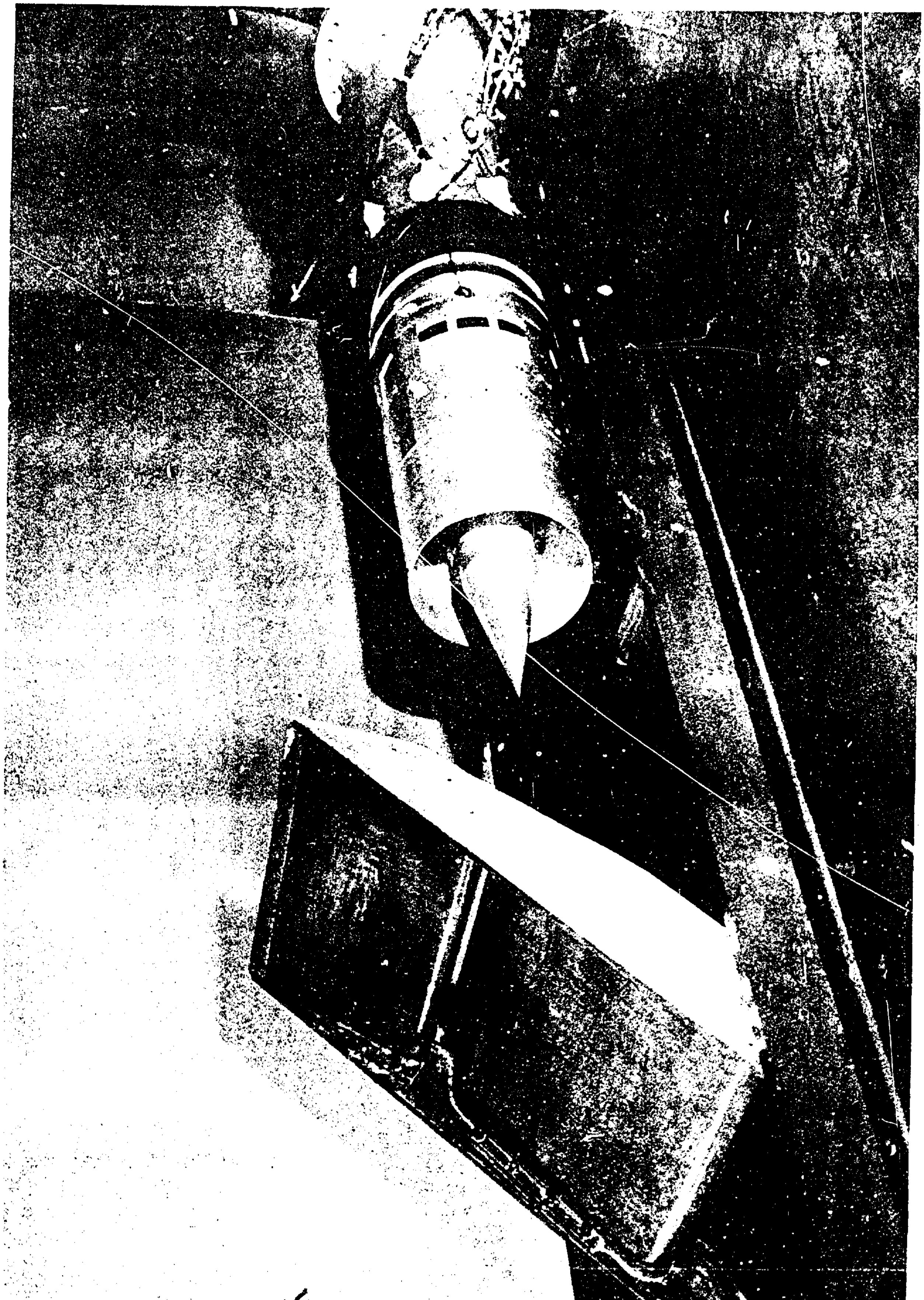
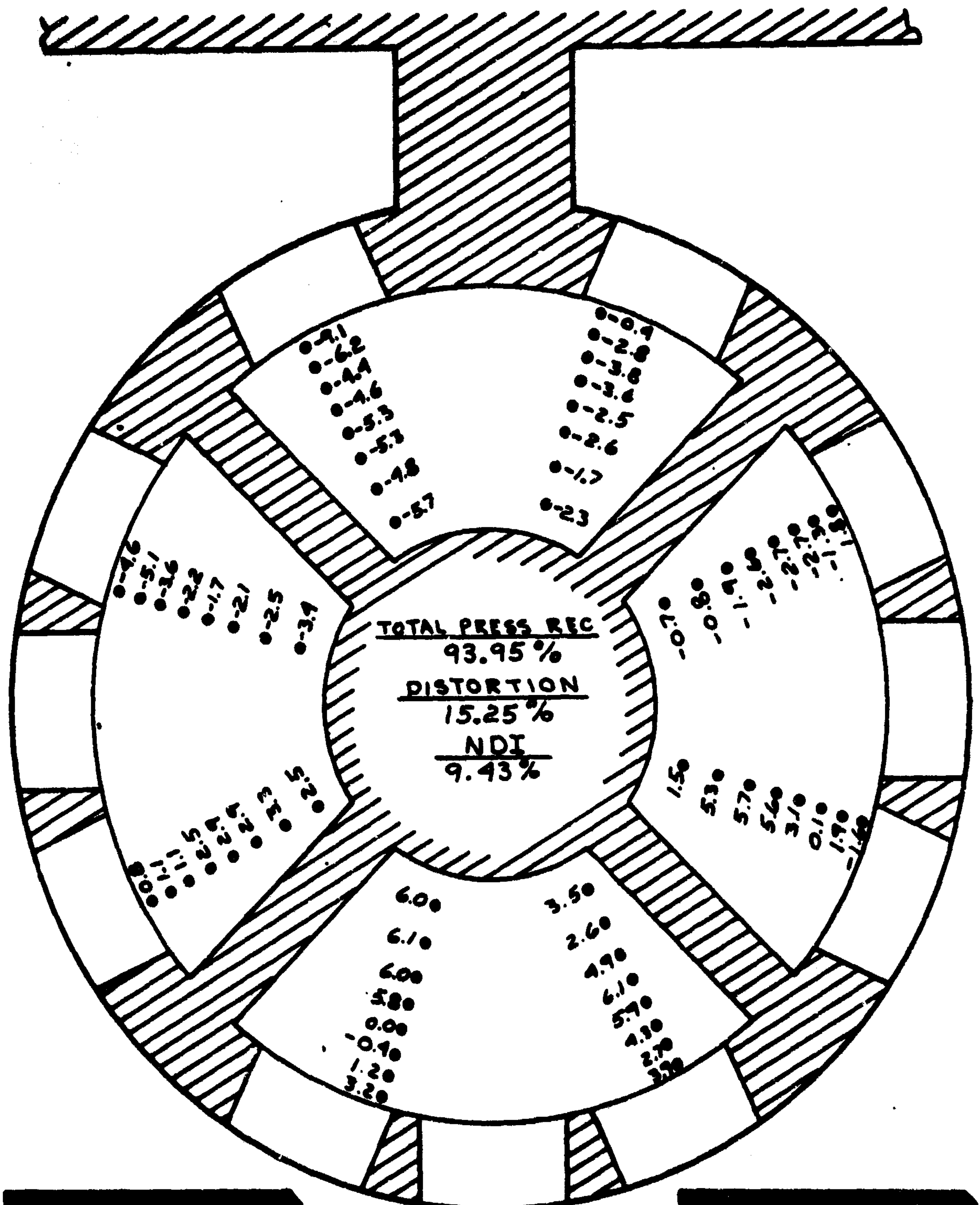


Figure 78. In board Flap and Inlet Relationship



CORRECTED WEIGHT FLOW $W_c\sqrt{\theta_{T_2}}/\delta_{T_2}A_{LIP}$	0.1911 $\frac{LBS}{SEC\text{-}IN^2}$
WING	367D
COWL	MACH 2.6

CONTRACTION RATIO A_{TH}/A_{LIP}	0.730
DOOR AREA	17.4% A_{LIP}
FLAP ANGLE	47 DEG.
STRUTS	45 DEG.
VELOCITY	175 KTS.

Figure 79. Compressor Face Map – Low Speed, Flaps Down

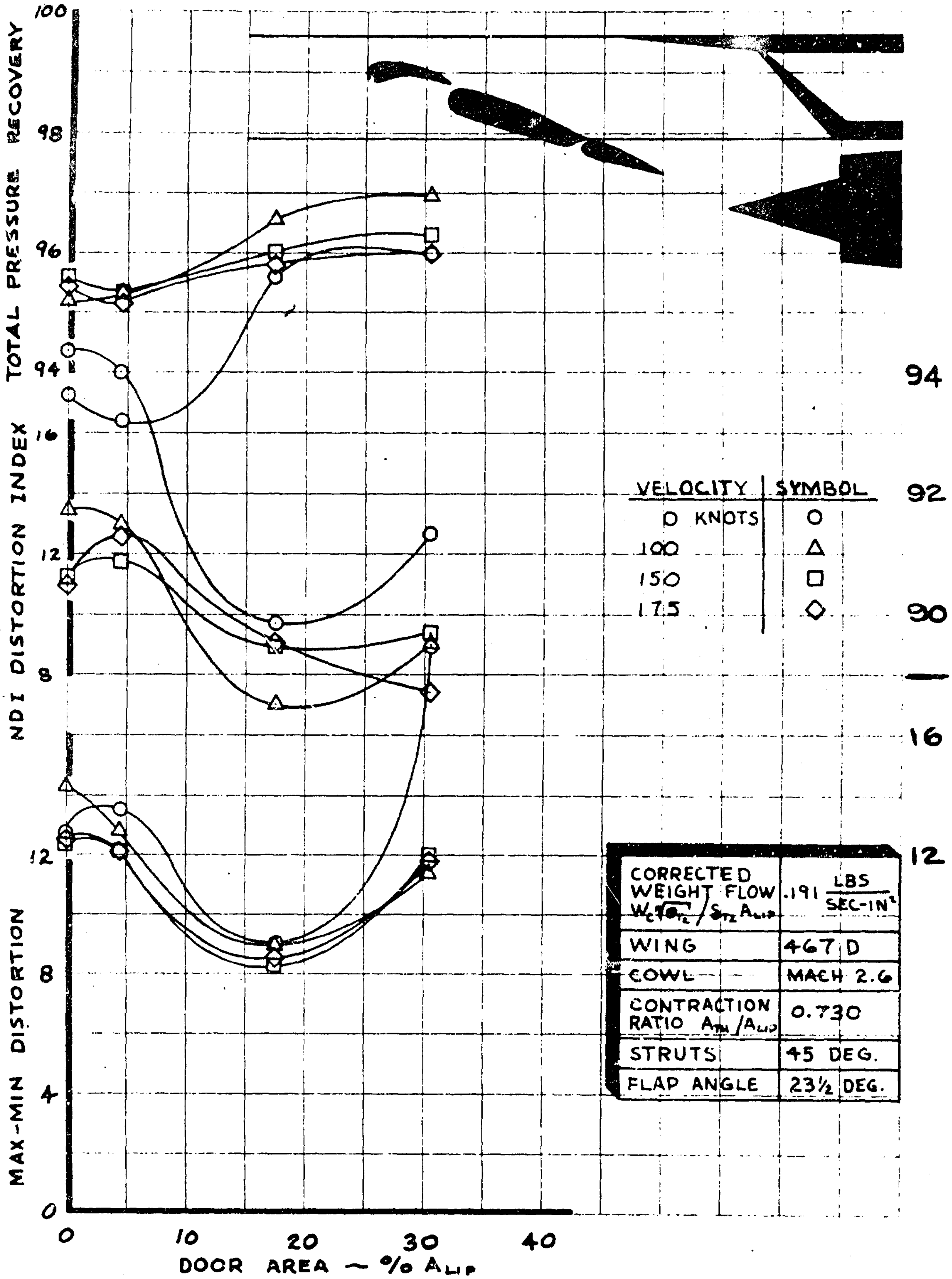


Figure 80. Effect of Takeoff Door Area

III. Description of Technical Progress (continued)

1302. Air Induction System (continued)

(c) **One-Fifth** Scale Model Drag Tests

Inlet bypass and spillage drag were determined for an isolated engine pod in the Cornell Aeronautical Laboratory 8-by 8-foot transonic wind tunnel during June. The test Mach number range was 0.7 through 1.3.

Schematic drawings of the bypass model configurations are shown in Fig. 81. The internal approach angle to the bypass flaps was changed by use of inserts on selected bypass models. Figure 82 shows the model before installation in the test section. The design and installation detail of a 30-degree short flap bypass segment is shown in Fig. 83. Figures 84 through 86 show three of the models installed in the test section of the Cornell 8-by 8-foot transonic tunnel.

Preliminary data have been received and is being analyzed.

(d) Test Schedule

Figure 87 shows the schedule of various propulsion testing through October 1966.

(2) Analysis, Design and Test of Engine-Size Inlets

(a) Centerbody Leakage Test

The pre-prototype centerbody leakage test is on schedule and should be completed by 29 July 1966. Data is currently being reduced and assessed with results to be reported in the August report. The leakage test program is being expanded to include isolation of leakage from the longitudinal and circumferential seals. This testing will be conducted early in August. Figure 88 shows the test chamber with the centerbody installed.

1303. Air Induction Control

(1) Inlet-Engine Simulation

Dynamic simulation of the combination of inlet-engine mathematical models is now complete for the Mach 2.7, 60,000 foot cruise and Mach 2.2, 49,400 foot climb conditions. In this series, a simple inlet control system without any compensation components or anticipatory circuit was used. The simulation results are being analyzed to determine if any additional circuit is required. Two examples of simulation results are presented in Figs. 89 and 90.

(2) Control Sensor Bench Test

Frequency response tests of bench simulated inlet centerbody loop and normal shock loop, using Hamilton-Standard and Marquardt sensors and Boeing designed electronic sensors, are now complete. Bode plots of the tests were analyzed to derive transfer functions of the loop components and the mathematical models of the control loops were obtained.

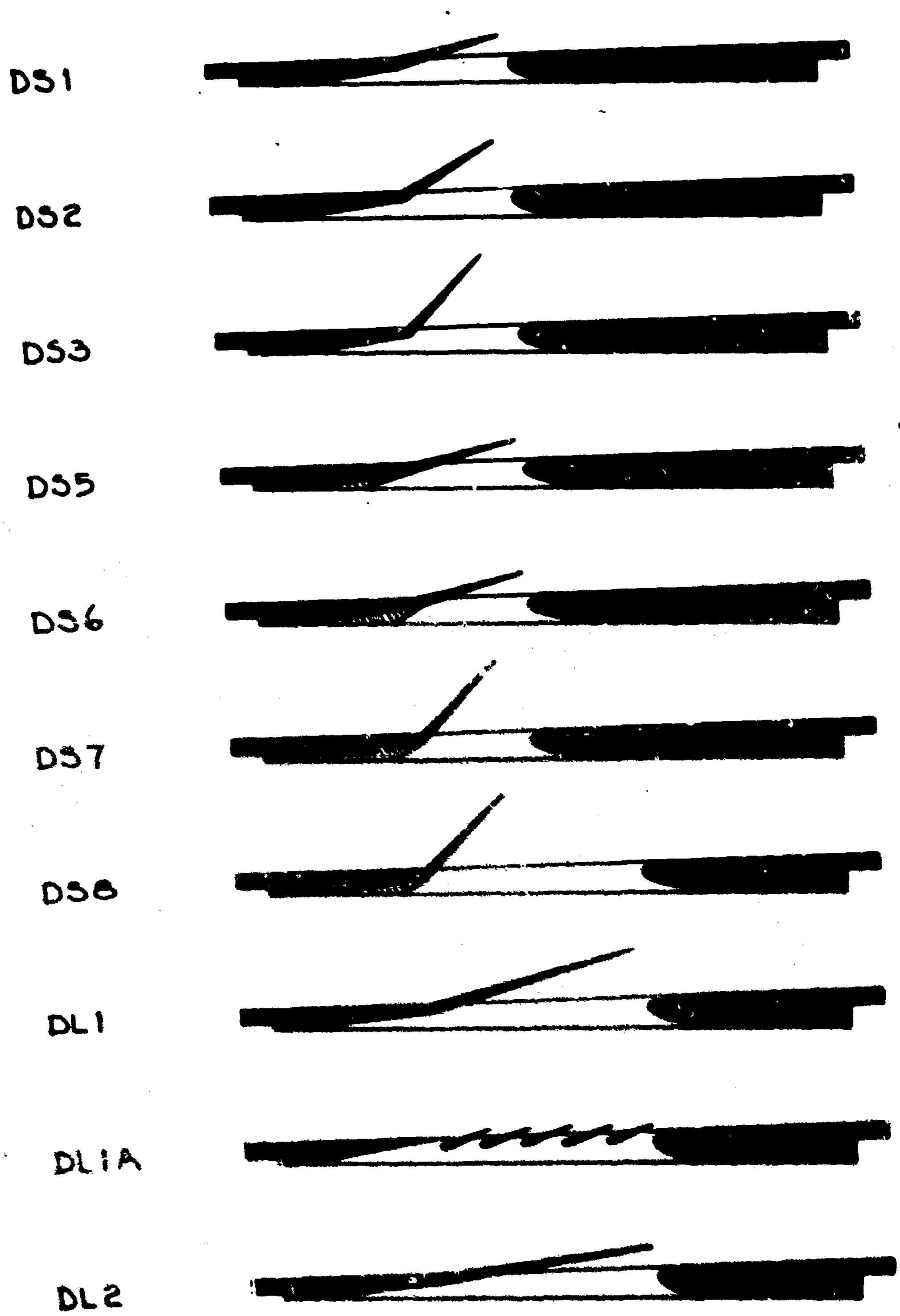


Figure 81. Schematic – Bypass Model Configurations

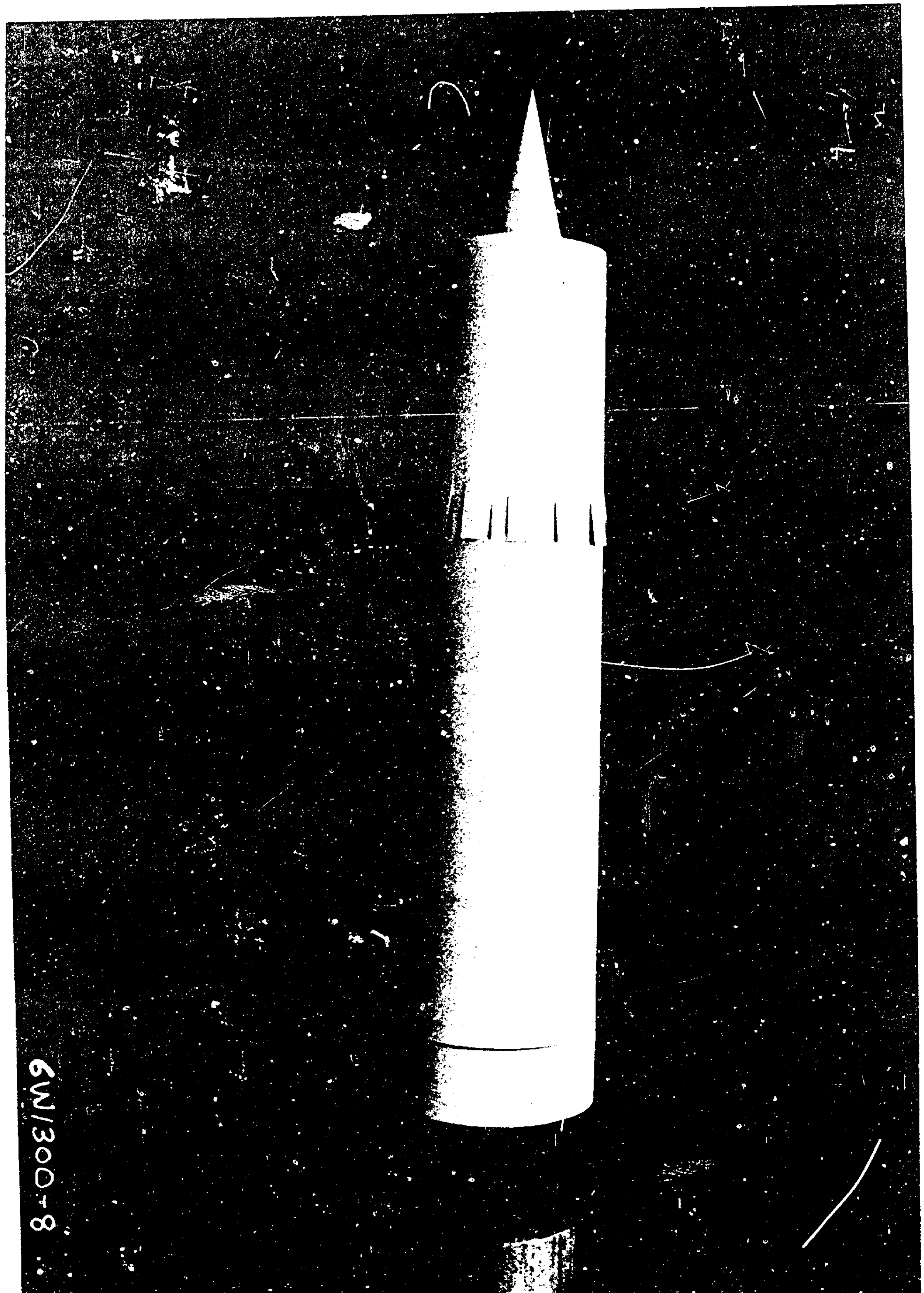


Figure 82. One–Fifth Scale Inlet Bypass Model

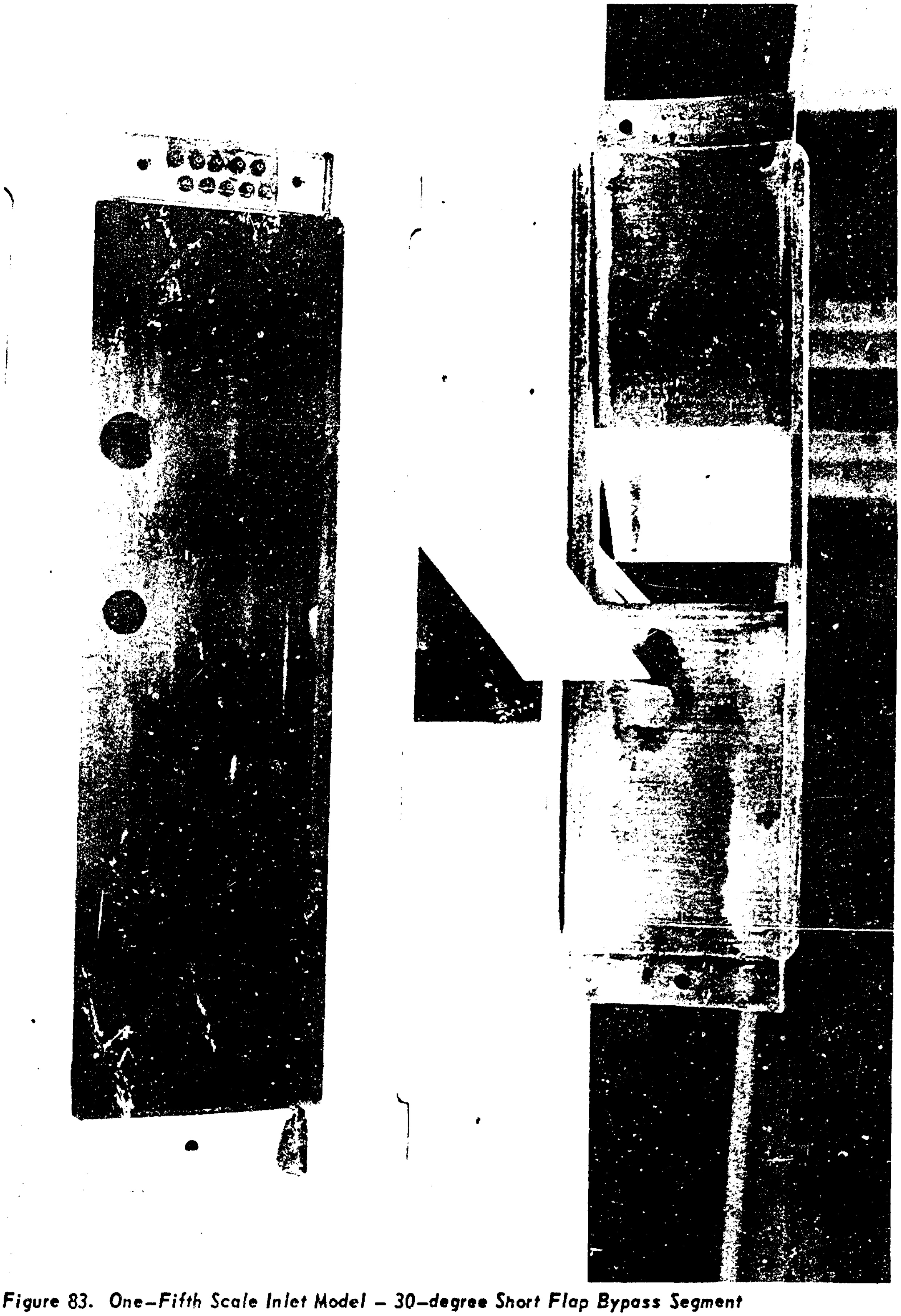


Figure 83. One-Fifth Scale Inlet Model – 30-degree Short Flap Bypass Segment

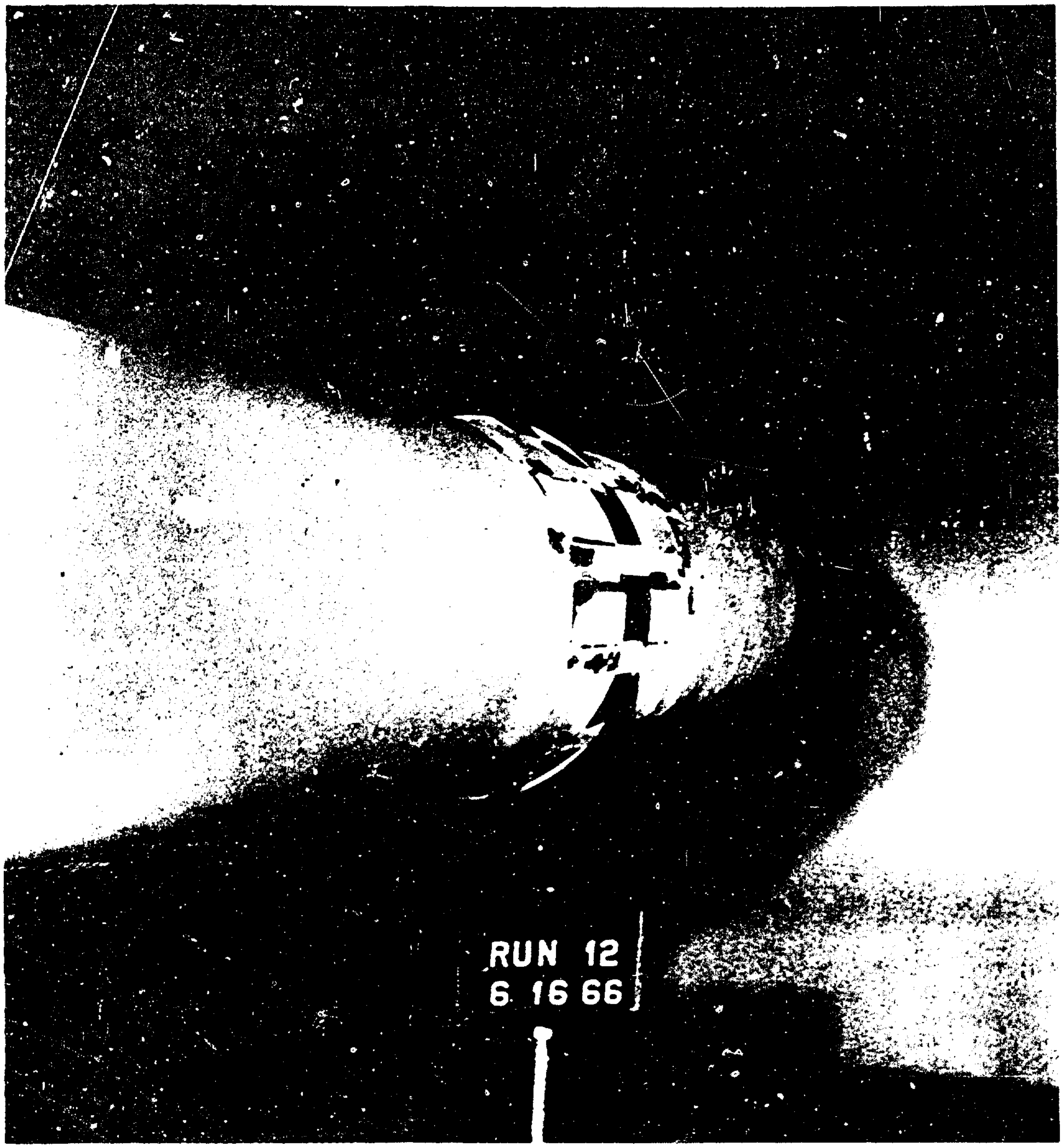


Figure 84. One – Fifth Scale Inlet Bypass Model – Cornell 8x8 Tunnel

Figure 85. One–Fifth Scale Inlet Bypass Model – Cornell 8x8 Tunnel

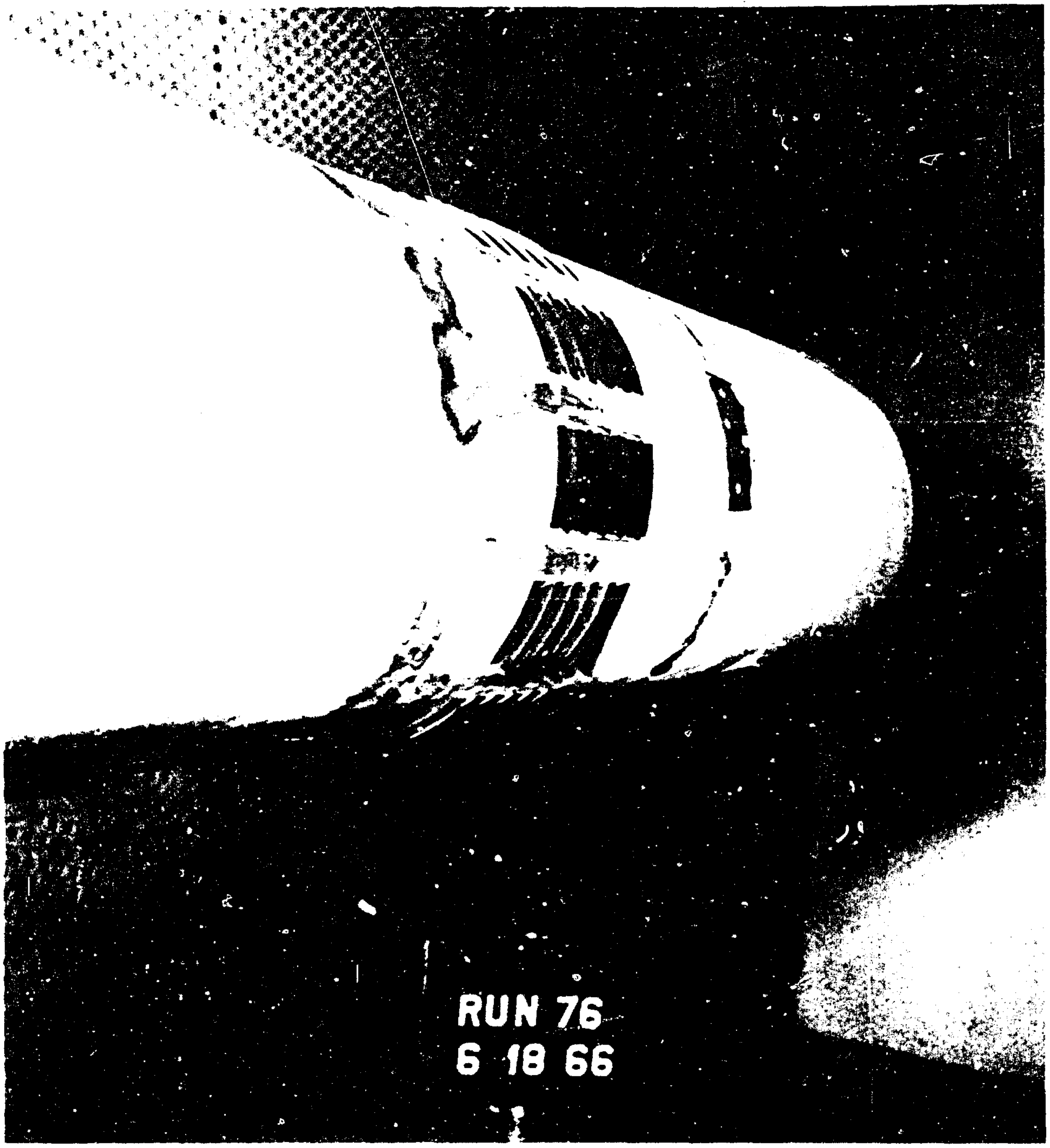


Figure 86. One–Fifth Scale Inlet Bypass Model – Cornell 8x8 Tunnel

MODEL DESCRIPTION

Fluid Control for Stability Bleed Augmentation
Inlet Throat Vortex Valves
Facility: Bench Test
18- by 18-Inch VW Tunnel,
1/5-Scale Inlet with Vortex Valves

Effects of Subsonic Diffusor/Bypass Plenum
Contours on Recovery and on Distortion
3-inch Inlet
Facility: 6- by 6-Inch VW Tunnel

Inlet Buzz Stability and Starting Characteristics
3-inch Inlet
Facility: 6- by 6-Inch VW Tunnel

Inlet Performance and Control System Evaluation
1/5-Scale Model
Performance and Control Signals. Fixed
Geometry Performance
Variable Diameter Centerbody, Performance and
Control Signals. Variable Centerbody and
Bypass System
Control Signal Study and Analog Controller Operation
Control Dynamics Test
Facility: 18- by 18-Inch VW Tunnel

Inlet Control Pressure Signal Test in the
Unstarted Mode, M=1.2-1.8
3-inch Inlet
Facility: 18- by 18-Inch VW Tunnel

Inlet-to-Inlet Interference-Fence Requirements
on B2707
Facility: 4- by 4-Foot BSWT

Subsonic Diffusor Bends-Inlet, Engine centerline
not aligned
3-inch Model
Facility: 6- by 6- Inch FW Tunnel

Reverser Ingestion Test
1/20 Scale Airplane Model
Facility: 9- by 9-Foot Low-Speed Tunnel

Nozzle Performance Test
5-inch Models
GE & P&W Nozzles
Facility: Static Rig
8- by 10-Foot BSWT

Reverser Performance Test
1/10-Scale
Facility: Static Rig

Takeoff; Inlet Choked Model Testing and
Inlet-Airframe Low-Speed Compatibility Tests:
1/10 Scale - Takeoff, Noise, B-2707 Config
1/3-Scale Inlet - J85 Engine Test
Facility: 9- by 9-Foot Low-Speed Tunnel

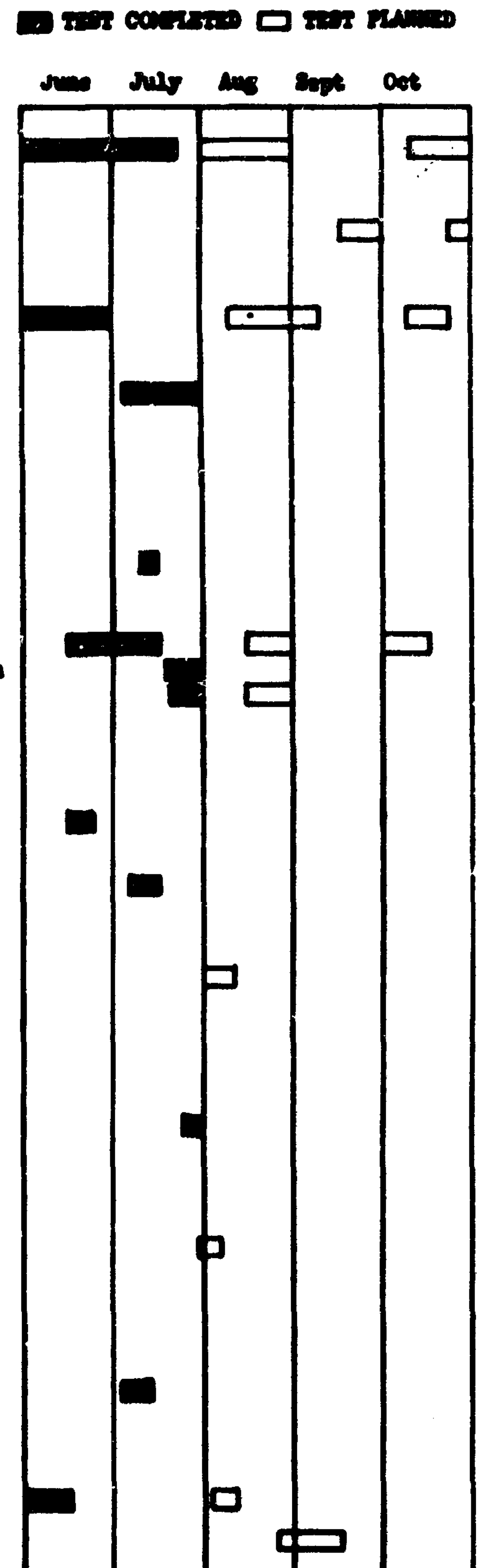


Figure 87. Propulsion Testing Schedule

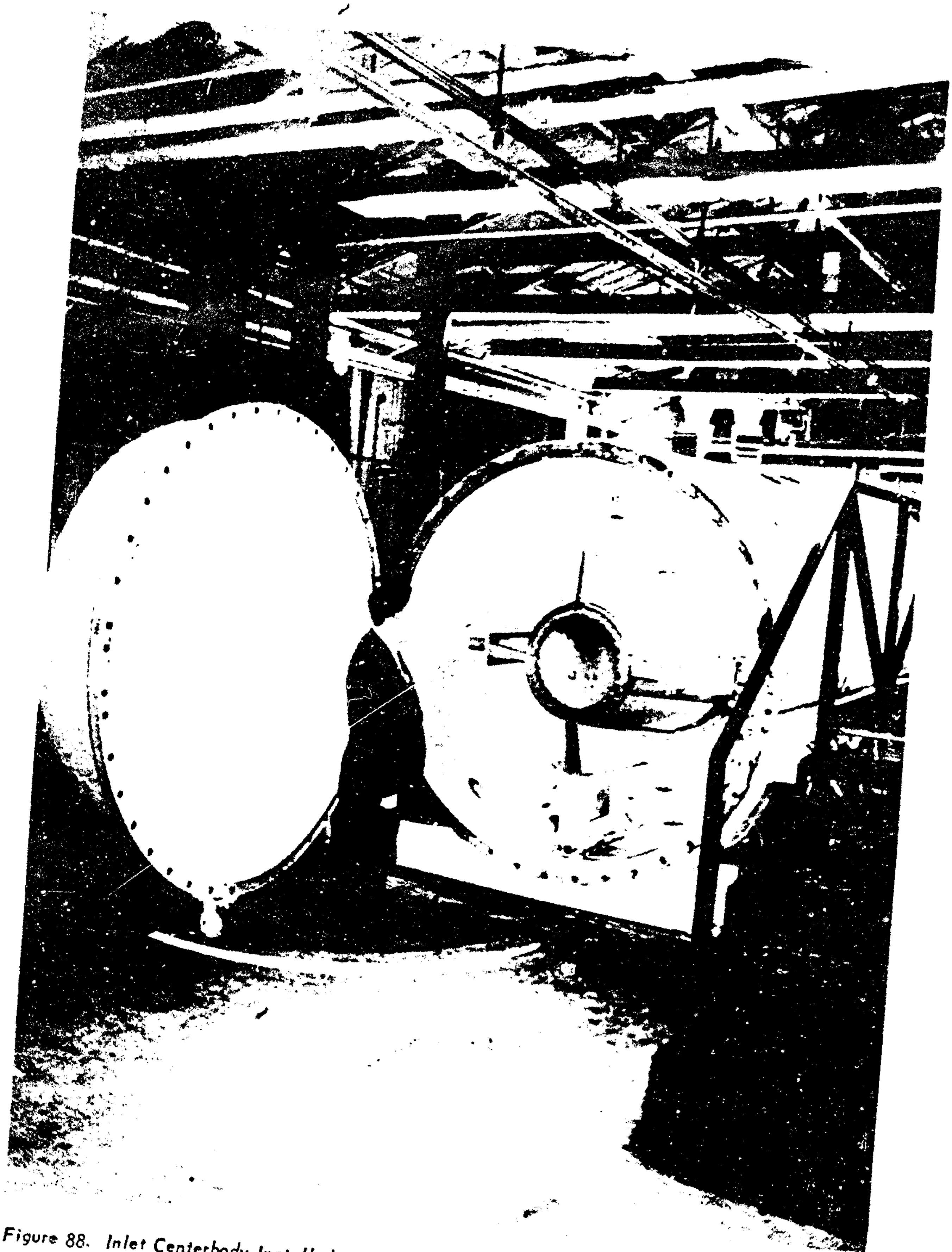


Figure 88. Inlet Centerbody Installed in Test Chamber

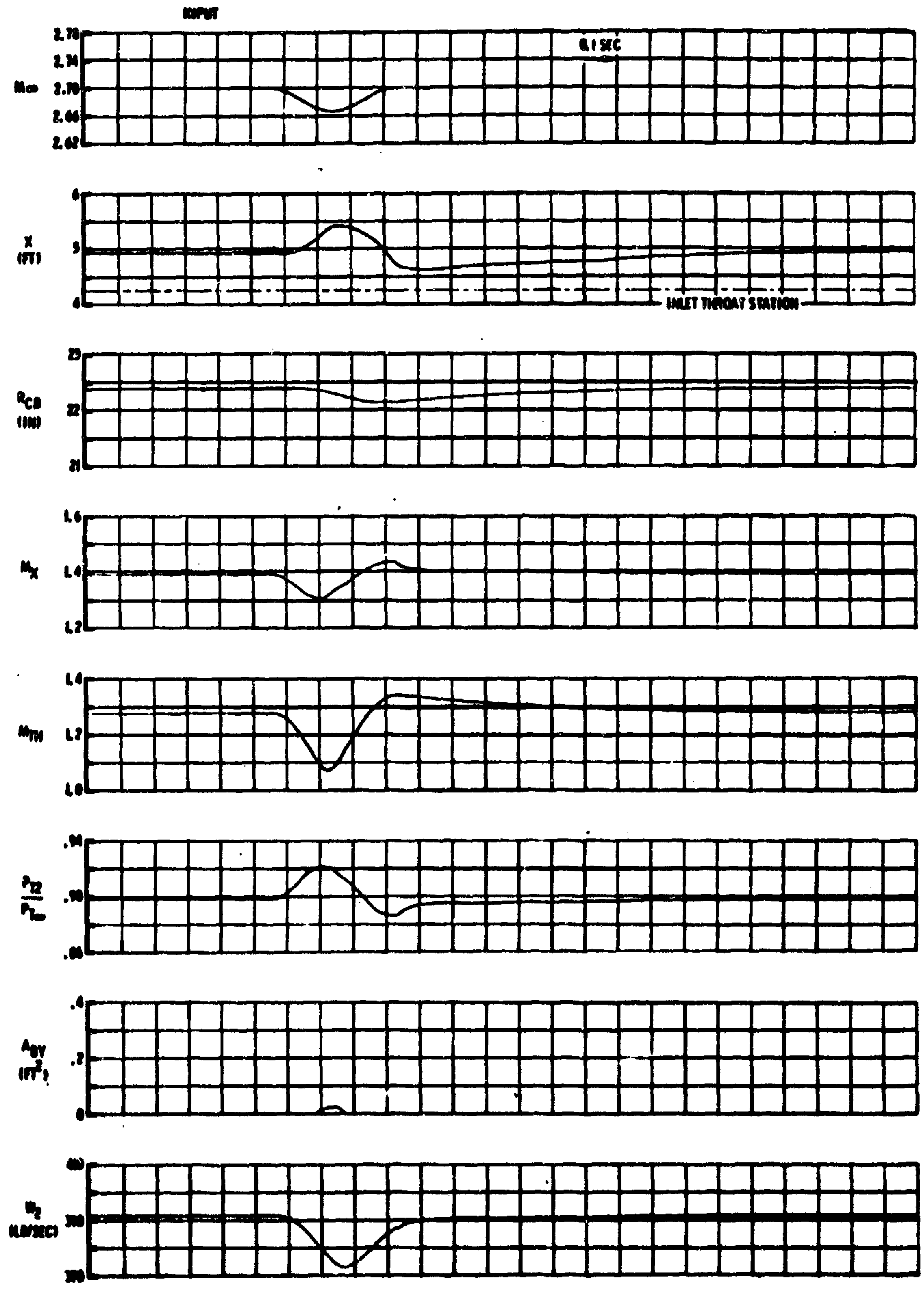


Figure 89. Transient Due to Gentle Tail Gust – P & W Engine and Inlet; Mach 2.7, 60,000 Ft. Cruise

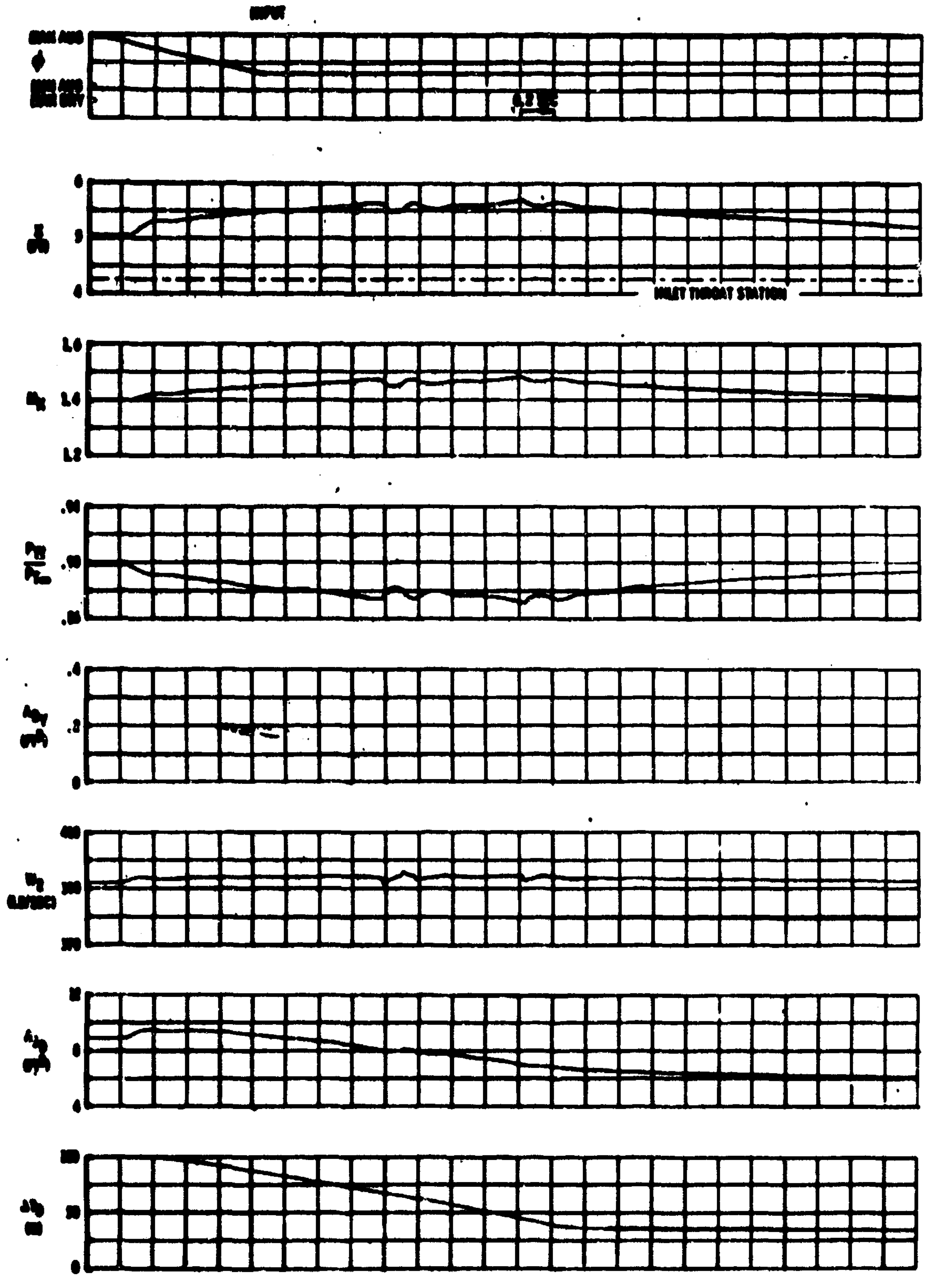


Figure 90. Transient Due to Power Lever Decrease, Max to Partial Augmented Power – P & W Engine and Inlet; Mach 2.7, 60,000 Ft. Cruise

1303. Air Induction Control (continued)

The summary of the loop frequency response tests is presented in Table XXIX. The table shows the break-off frequencies and the damping ratios of loop response curves that are approximated by second order transfer functions. Table XXX presents the transfer functions of sensors derived from the sensor alone tests reported in the earlier progress reports. This information will be valuable in future work, where the sensors are used as components of control loops.

(3) Wind Tunnel Tests

The 11.24-inch lip diameter inlet model was tested in the 18- by 18-inch wind tunnel to obtain control signal pressure characteristics and the centerbody control performance. Initially, three solid centerbodies designed for Mach 2.6, 2.2, and 1.8 were used; currently a variable geometry centerbody is used. Some test results are now available and they are being analyzed.

The variable centerbody model was tested with an analogue computer controller and a breadboard electronic controller. The centerbody loop only was tested with variations in inlet Mach number. Both controllers performed satisfactorily for the disturbances simulated.

(4) Inlet Control System Proposal Evaluation

Proposals in response to the inlet control procurement specification were received from three control suppliers (Hamilton-Standard, Marquardt, and AiResearch) and the three different system concepts presented are being evaluated.

1304. Propulsion Controls

Engine control system operation has been negotiated with the two candidate engine manufacturers and the sequence of operation and power settings have been established. Preliminary layouts of the engine control linkage have been made for the mockup engines.

1305. Propulsion Installation

13051. ENGINE PLUMBING AND WIRING

Preliminary layouts of engine plumbing for both candidate engines have been made. Separate layouts of the plumbing interface between the engine and airframe are being made.

13053. ENGINE DRAINS

Layouts have been completed that define the drain systems for each of the candidate engines.

Table XXIX. Natural Frequency and Damping Ratio Table for Second-Order Approximation of Bench Test Closed-Loop System Bode Plots

Pressure Ratio Sensor	Control Loop	Simulated M_L	Optimized AT M_L	fn (CPS)	6
Hamilton-Standard	Centerbody	1.80	1.80	2.20	.57
		2.00		2.00	.70
		2.20		1.65	.80
		2.55		1.20	.90
		2.55	2.55	1.80	.64
Boeing Electronic		1.80	1.8 & 2.2	10.30	.57
		2.00		8.30	.55
		2.20		8.00	.60
		2.55		7.00	.80
Hamilton-Standard*		1.80	---	2.40	.63
		2.00	---	2.20	.85
		2.20	---	1.90	1.13
		2.55	---	1.50	1.45
Hamilton-Standard	Normal Shock	1.80	1.80	1.60	.64
		2.20		1.21	1.21
		2.55		1.10	1.60
		2.55	2.55	1.90	.55
Boeing Electronic		1.80	1.80	3.50	.40
		2.55	1.80	6.10	1.66
		2.55	2.55	6.00	.70
Marquardt		1.80	1.80	2.40	.57
		2.55	1.80	1.70	.90
		2.55	2.55	2.50	.90

* Means Hamilton-Standard hydraulic servo valve used

Table XXX. Sensor Representative Transfer Functions

Sensing Unit	Transfer Function
Boeing Electronic Inlet Controllers	$K_1 e^{-0.0011S}$
Hamilton-Standard Pressure Ratio Sensors	$\dfrac{K_2(65.3)^2 e^{-.00556S}}{S^2 + 2(.8)(65.3)S + (65.3)^2}$
Marquardt Pressure Ratio Sensor	$\dfrac{K_3(1 + 0.199S)}{(1 + .0532S)(1 + .0023S)}$

III. Description of Technical Progress (continued)

13054. ENGINE INSTRUMENTATION

The final instrumentation requirements for both engines have been agreed upon by Boeing and both of the candidate engine manufacturers. A preliminary specification for a direct reading thrust measurement system has been released. A force cell integrated into a thrust link in the mount system is used to transmit load data into a computer which in turn transmits signals to an indicator. The indicator will provide digital readout of actual net thrust in pounds in addition to dial indication of percent of maximum available thrust.

1307. Exhaust/Reverser System

(1) Nozzle Performance

The revised GE exhaust nozzle is being evaluated. Test data have been received that tends to confirm the levels of performance currently used by Boeing for the GE engine.

(2) Thrust Reverser Testing

The one-twentieth-scale model of the 733-414E SST configuration used in a previous reverser exhaust ingestion test has been converted to the B-2707 configuration for a quick look at its reverser exhaust ingestion characteristics. Tests are scheduled for early August.

(3) The proposal pod configuration for each engine is refined over previous pods to provide a conical external contour for the secondary nozzles. This provides even pressure distribution around the periphery of the nozzle plane and facilitates fabrication of nozzle components. The horizontal stabilizer is modified as shown on layouts P-ENG-582 and P-ENG-575 to permit effective discharge of reverser gas over the wing without increasing the drag of the airplane.

13073. NOZZLE SECONDARY AIR

The GE4/J5P engine has been redesigned to provide a ducted secondary air transfer system. This redesign by General Electric eliminates the requirement for pressurized cowling with its associated problems.

1308. Noise

The two most promising noise suppressors tested acoustically, as reported in the May progress report, have been evaluated for performance characteristics in the Boeing Mechanical Laboratories. Figure 91 is the high-pressure ratio rig with nozzle and ejector installed on which the performance measurements were made. Figures 92 and 93 show the suppressors as tested. Thrust loss is presented as a function of penetration into the primary flow for various nozzle pressure ratios on Fig. 94. This data indicates a thrust penalty of less than 5 percent for the suppressor configuration that provides an 8.5 PNdb reduction in sound levels at maximum augmentation power setting.

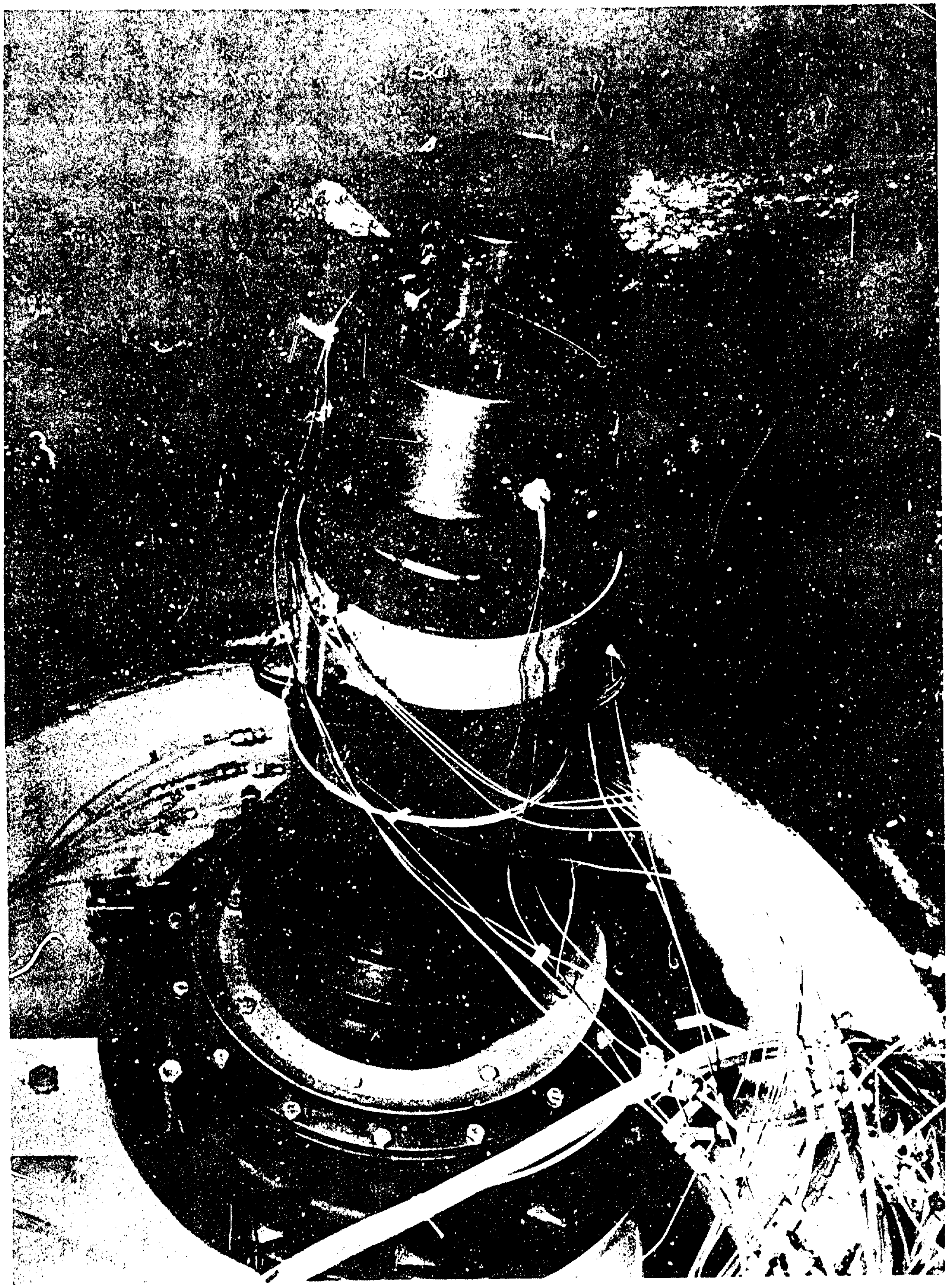


Figure 91. Noise–Suppressor–High Pressure Ratio Rig

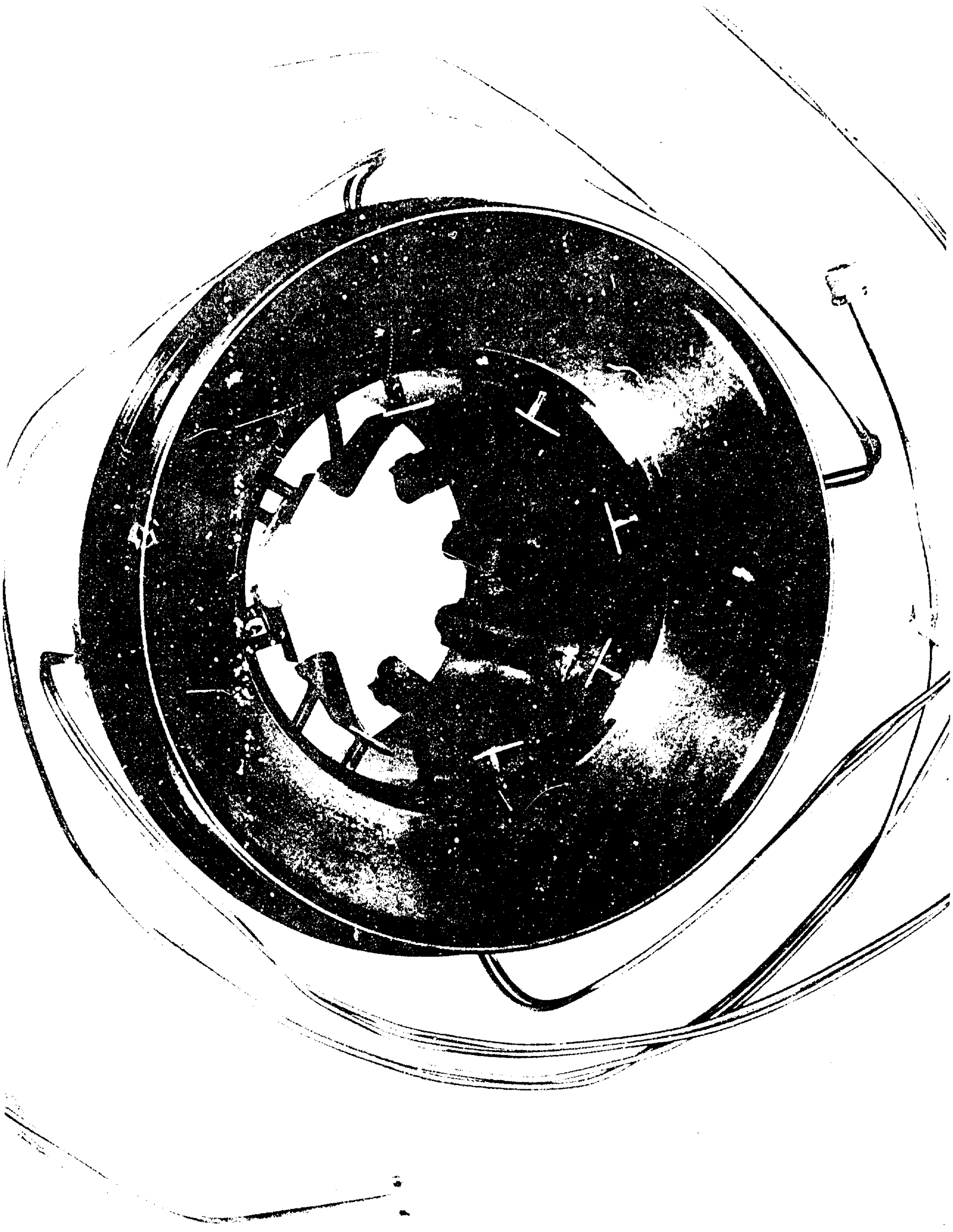


Figure 92. Noise Suppressor Model – Chute Configuration (30 % Penetration)

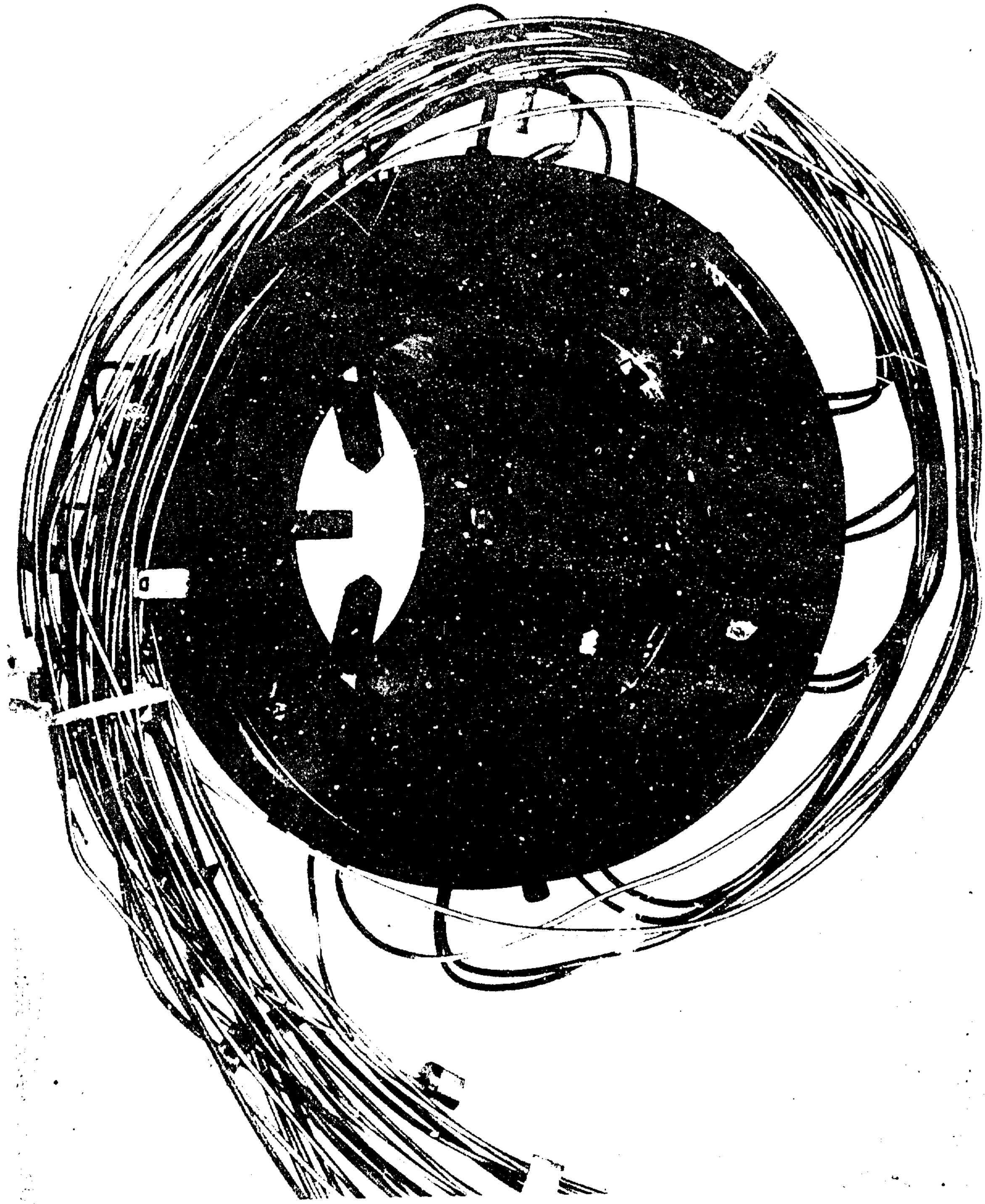


Figure 93. Noise Suppressor Model – Scoop Configuration (50 % Penetration)

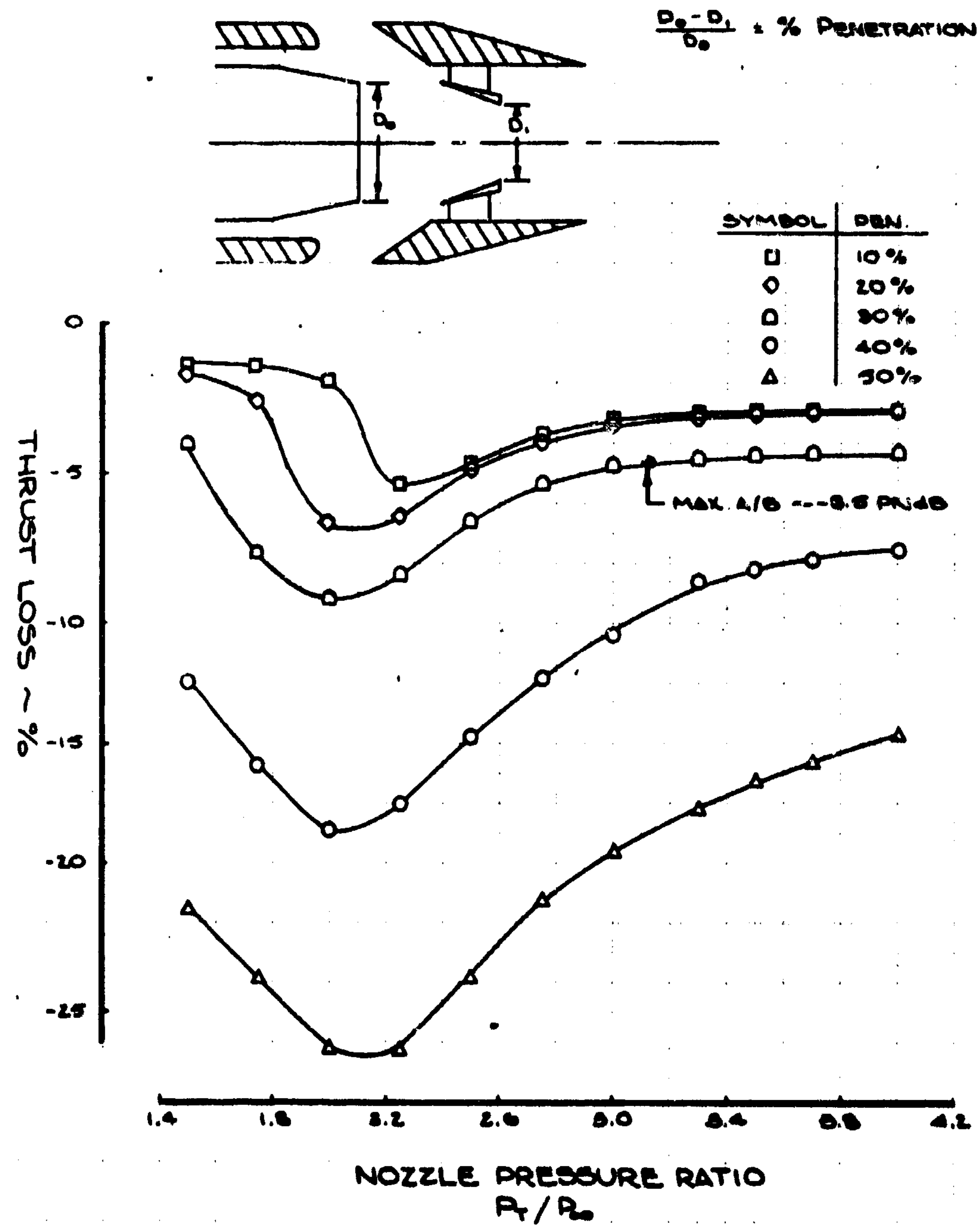


Figure 94. Thrust Loss

III. Description of Technical Progress (continued)

1309. Engine Coordination

Engine/Airframe Technical Agreements, D6A10198-1 (GE) and D6A10199-1 (P&WA), have been negotiated with each of the prospective engine manufacturers. Meetings between Boeing and General Electric personnel were held at Boeing from July 13 through July 18. Meetings between Boeing and Pratt & Whitney Aircraft personnel were held at P&WA on June 28 and 29, and at Boeing from July 8 through July 13.

To resolve problems relative to accessory capsule and secondary air duct locations within the engine pod, a group of General Electric personnel were present at Boeing July 5 through July 8. As a result of the coordination between Boeing and GE personnel, a proposed engine configuration, 4013019-460, has been offered by GE.

14. PRODUCT SUPPORT

1400. Product Support General

Maintenance Engineering
In the current reporting period, Maintenance Engineering participated in design reviews of the flight deck, electrical, air conditioning, and hydraulic systems.

Maintenance engineers participated in the presentation and conference with the following Airline SST Committee Specialist Team meetings:

(a) Structure and Landing Gear: June 13 - 15

(b) Propulsion: June 21 - 22

(c) Ground Support: June 22 - 23

On June 13, a trip was made to Edwards AFB, California, to obtain information on a system of the YF-12 (SR-71) and F-111.

1401. Data and Handbooks

14010. DATA AND HANDBOOKS GENERAL

Preliminary Flight Crew Operating Procedures
Rough draft copy of system descriptions and procedures has been completed for the following systems:

Air Conditioning and Pressurization
Fuel
Electrical
Main hydraulic

14010. Data and Handbooks General (continued)

Inlet hydraulic
Inlet controls

Engine system description and procedures are in work. Continuous updating will be required for each system throughout development.

Technical Publications Specifications

Technical publications specifications prepared by the Publications Group for the FAA Approved Airplane Flight Manual, Operations Manual, and Maintenance Manual were submitted to TWA, VAL, AA, and PAA as of June 29, 1966. During the period July 15, 1966 through July 20, 1966, a representative of the Publications Group contacted each of the airlines for comments on the Airplane Flight Manual and Operations Manual. All airlines were appreciative of this coordination effort. Comments made by the airlines are contained in the specifications being submitted with our work plan.

1403. Training and Training Equipment

Training Analysis

Procedures for performing the training analysis and standards for the identification and description of the training requirements were established. Using these, an initial analysis of a significant part of the maintenance data was accomplished. To the extent maintenance task data were available, those tasks for which training is required were identified, and the general nature of the training and training aids required was established.

Training Requirements and Course Development

The training requirements information resulting from this initial analysis were used to structure preliminary courses of instruction for operations and maintenance personnel. Initial studies of training methods were performed, and preliminary selections of methods were made. Preliminary training equipment and training aids requirements were established.

Flight Crew Training Requirements

Flight crew operations tasks and tasks elements data, being used in crew work load analyses, are being studied for flight crew ground training and flight simulation.

Training Equipment Requirements

Plans for the modification and utilization of the Flight Deck Systems Integration Simulator for Phase III training have been formulated.

1403. Training and Training Equipment (continued)

Training equipment requirements for Phases III, IV, and V have been refined. Preliminary identification of specific items of training equipment has been made.

Training Flight Simulator requirements have been refined and have been defined in terms of procurement requirements.

Training equipment and flight simulator requirements and usage studies are continuing.

1404. Ground Support Equipment

14040. GROUND SUPPORT EQUIPMENT GENERAL

The Summary List of Ground Support Equipment has been coordinated for internal requirements and has been released in its final form for GSE cost estimating and requirements planning.

The Ground Support Equipment Requirements Specification is in the process of being reviewed for final release. This specification documents the GSE general design requirements, a consolidated list of GSE arranged by airplane systems, and contains individual GSE item specification sheets that define the individual design requirements. This document will be submitted as part of the Phase III proposal documentation.

GSE Requirements and concepts to support the B-2707 airplane were presented to the Airlines SST Ground Support Committee on June 22-23.

14041. SERVICE GROUND SUPPORT EQUIPMENT

The engineering analysis of the airplane ground handling and service requirements has been completed. The results of this analysis will appear in the Operations Suitability Report of the Phase III proposal. Individual specification sheets have been prepared for the Service GSE needed to support the B-2707 and are included in the GSE Requirements specification.

14042. MAINTENANCE GROUND SUPPORT EQUIPMENT

An analysis of the SST was completed to define the Maintenance GSE requirements, and data sheets were prepared for inclusion in the GSE Requirements specification. In addition, detail performance/design specifications have been prepared for major items of GSE wherein cost, complexity, test requirements, etc., are significant. These specifications will be available for on-site review.

III. Description of Technical Progress (continued)

14051. AIRPORT COMPATIBILITY

The Pavement Requirements Document and the ground maneuvering studies have been revised to reflect the current airplane configuration. Studies are continuing on terminal area parking and use of existing passenger loading devices. Methods of multiple door loading from two gate positions are being considered for increased passenger comfort and faster loading. The effects of engine plume impingement on runways are being evaluated.

IV. AIRLINE COORDINATION

A. AIRLINE SST COMMITTEE COORDINATION

The latest U.S. Airline SST Committee and Boeing joint review of the B-2707 configuration was held on June 6, 1966, in Seattle. The committee was scheduled to meet with Boeing again on July 21-22, 1966; however, the meeting has been postponed due to the airline strike. Arrangements for the postponed meeting have been completed so that it may be held as soon as possible when the committee can be reconvened. This meeting will discuss the proposal configuration of the B-2707 and the Boeing engineering responses to the 265 recommendations that were submitted during earlier meetings with the Airline SST Committee and the Specialist Teams.

B. AIRLINE SST SPECIALIST TEAMS COORDINATION

During June and July, Boeing has met with the U.S. Airline SST Specialist Teams, as listed below in the development of the B-2707 configuration. These meetings have been characterized by frank, collective discussions of airline requirements relating to the subject areas. Each Specialist Team recommendation has been subsequently evaluated and given consideration in the B-2707 design.

Specialist Team	Date
Environmental Control	June 1-3
Fuselage - Payload Accommodations	June 7-8
Hydraulics and Flight Controls	June 7-8
Performance, Economics, and Noise	June 7-8
Structure and Landing Gear	June 13-15
Propulsion System	June 21-22
Fuel System	June 22-23
Ground Support	June 22-23
Electrical System	June 27
Avionics, Flight Deck, and Operations	June 28-30

C. MODEL SPECIFICATION

The Model Specification, D6-17850 was revised and re-issued June 30, 1966, to define the current B-2707 configuration. Also submitted to the FAA on June 30 was a Category I change outlining the significant differences and reasons in the evaluation of design from the Boeing 733-390 configuration to the B-2707. A meeting with the FAA is planned for early August to review the outline, make-up, and material coverage in the Model Specification.

Customer Engineering conducted comprehensive model specification reviews with Pan American Airways and Trans World Airlines in July. These reviews generated approximately 500 requests for airplane/model

specification changes, of which approximately 50 percent are being incorporated into the B-2707 basic design and/or model specification to be submitted on Sept. 6, 1966. Other items requiring more detailed study will result in further design improvements.

D. AIRLINE COORDINATION

Personnel from the following airlines were given mockup tours and technical briefings:

Air Canada
American Airlines
Cathay Pacific Airways
Deutsche Lufthansa
El Al Israel Airlines
Pan American World Airways
Pakistan International Airlines
Qantas Empire Airways

E. TECHNICAL BRIEFING AREA

The Technical Briefing Area is in the final stages of production and is expected to be complete on August 5, 1966. Subsequently, the area will be kept up to date to reflect the latest airplane configuration.

F. FAA COORDINATION

On June 3, 1966, H. W. Withington, F. A. Maxam, and other engineering management personnel conducted a configuration review in Washington, D.C., for all FAA/SST engineering sections. Furnished to the FAA following the briefing were copies of a two-volume brochure that included all data used during the review.

Nine visits were made to Boeing by personnel from the FAA and related agencies during June and July. During these visits, reviews of performance, system design, airworthiness certification, and other subjects related to airplane design were conducted.

Approximately 30 transmittals of subsystem reliability analyses, vendor progress reports and coordination minutes, and other engineering data were forwarded to the FAA/SST office and related agencies during June and July in response to the Phase II-C work plan, personal requests, and other requirements.

On July 27-28, Mr. I. Hoover, Executive Officer, and 18 other members of the FAA/SST office and evaluation team members visited Boeing for a management review of the B-2707 airplane program. The primary objective of the June 27-28 review was to provide a final in-person familiarization with the SST effort and answer specific questions.

V. STATE-OF-THE-ART RESEARCH

Electrical Systems

A 60-kva, 3-phase frequency converter utilizing a circular cylinder SCR design has been built by Lear-Siegler, Inc. at a weight decrease of 10 lb under past designs. The SCR has lower thermal resistances to heatsinks than stud-type SCR's and assembly is simplified, consisting only of clamping between surfaces. The regulating-firing control is in monolithic integrated logic modules mounted on the converter structure.